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WASTE WATER LAGOON CRITERIA FOR MARITIME CLIMATES

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Corvallis, Oregon

1 May 1962

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Progress Report No. 2

WASTE WATER LAGOON CRITERIA FOR MARITIME CLIMATES

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Corvallis, Oregon

May 1, 1962

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SUMMARY

Waste water oxidation lagoon studies are being conducted at Oregon State University to establish criteria for their use in the maritime climates of the Pacific Northwest. The study was initiated with the assistance of the State Sanitary Authority, the League of Oregon Cities, City of Corvallis, and several consulting engineers who recognize that oxidation lagoons promise an economic solution to the waste disposal problem of many small municipalities and industries that cannot afford more elaborate treatment methods.

An experimental facility was constructed consisting of two cells, each 1 acre in surface area and 3 feet deep on which studies are being conducted. Additional studies on other existing field installations are also included.

Knowledge of loading data as related to effluent quality and other basic parameters should make it possible to define the engineering criteria for application of lagoons to maritime regions. Emphasis is being placed on determination of basic factors influencing lagoon use under various conditions. These include surface reaeration mechanics, sludge accumulation and respiration, bacteriological quality, and disinfection requirements, together with other problems as defined in this report.

Progress made to date indicates that waste water lagoons may be successfully operated in the maritime areas of the Pacific Northwest during the periods of low solar energy without objectional odors or characteristics.

Progress Report No. 2

WASTE WATER LAGOON CRITERIA FOR MARITIME CLIMATES

INTRODUCTION

This progress report has been prepared for, (1) engineers and scientists of organizations considering this project for research grant support, (2) engineers for cities and industries having an interest in oxidation lagoons as a practical method of waste disposal, and (3) personnel participating in this and related research. Preliminary results have been summarized according to categories in the body of this report. Since much of the research is still in progress, specific conclusions have been made only to a limited extent where they are sufficiently justified by available data. Observational data have been included in the appendix for readers desiring more detail.

General Objective

The long-term goal of this project is to gain a better understanding of the biological, chemical, and physical mechanisms involved in the stabilization of organic wastes in oxidation lagoons. Since the practical necessity of applying lagoons to waste treatment needs in maritime climates is most pressing, emphasis during the initial phases of this project has been on loading criteria and related problems. A rigorous experimental approach has been taken, however, to many of the more fundamental problems that will be the bases of future investigations. It is firmly believed that a greater understanding of these more basic relationships will ultimately lead to the solution of waste treatment problems.

Method of Procedure

So that the results of this investigation will fulfill the twofold purpose of providing data useful for immediate application and yet help resolve some of the more basic problems, the research has been divided into two experimental approaches. The two-cell experimental lagoon, which is described in more detail later in this report, serves as the basic facility for testing. Related work in the laboratory and results of lagoon operation at other maritime locations are also used to substantiate findings. Basic data on loading, influent and effluent quality, efficiency, and weather are collected routinely, and serve as the nuclei of the project. Separate studies on reaeration, disinfection, oxygen production effects on the receiving streams, and others as enumerated in this report are coordinated with the basic

program and serve as areas of study for graduate students. While the problems of coordinating efforts are at times difficult, this approach has served to gather needed information and provide valuable training for sanitary engineering students.

General guidance is given to the project by a committee consisting of C.M. Everts, State sanitary engineer; G.W. Holcomb, head of the Department of Civil Engineering; John Porter, city manager of Corvallis, and Lloyd Clark, consulting engineer. The aid of these gentlemen has been invaluable in maintaining program objectivity.

Contributors

The initial project was undertaken in 1958 at the suggestion of representatives of the Oregon State Sanitary Authority, municipalities, and consulting engineers. Construction of the test facilities was accomplished under a grant of $5875 provided by the Oregon State Sanitary Authority. A single cell lagoon was completed in the fall of that year, and studies during the winter of 1958-59 were conducted by Mr. Gerald Whitney, graduate student, while being supported on a U.S. Public Health Service Traineeship. Studies during the summer of 1959 were financed by the Engineering Experiment Station and conducted by Mr. Thomas L. Miksch. Support for three years of study was received from the U.S. Public Health Service, National Institutes of Health, on December 1, 1959. The City of Corvallis, Oregon, has contributed considerable material aid in the form of a lagoon site, labor, and services throughout the project. Without their generous cooperation the project would not be possible.

Significance of This Research

The use of oxidation lagoons as an economic solution to the waste needs of cities and industries in the maritime climates of the Pacific Northwest depends upon the establishment of loading criteria, operational procedures, and the solution of related problems. While considerable research has been done at other locations, many of the problems are regional in character since they are affected by the climate and characteristics of waste quantity and quality. Since annual precipitation exceeds evaporation in the maritime areas, an effluent outfall results. It is felt that studies on bacteriological quality, disinfection requirements, and interpretation of effluent quality will aid in establishing lagoon feasibility. Because of low light intensities during rainy winter periods, accompanied by low temperature but open water conditions, the studies on sludge accumulation, oxygen production and reaeration are also important. Studies on factors contributing to odor nuisance and upon mosquito control will be most useful in guiding lagoon locations.

Many highly colored domestic and industrial wastes may possibly be treated by the lagoon method. Because of the large light extinction coefficient of such colored waste waters, photosynthetic production of oxygen by algae is severely limited even during the summer months. Reoxygenation of lagoons under these conditions must be largely from surface sources. Hence, studies of reaeration mechanics and development of experimental methods for determining reaeration constants are important. The Pacific Northwest maritime area is characterized by winters of high rainfall and low light intensities. Summer periods, however, have prolonged dry periods, and many streams available for effluent dilution have very low minimum flow. Studies on evaporation and water balance in the lagoon and interpretation of the effect of effluent quality upon the receiving stream during these periods is of major importance. Studies on seepage rates and soil sealing are included to provide needed information where ground water contamination is a problem.

DESCRIPTION OF EXPERIMENTAL FACILITIES

The experimental lagoon is located 600 feet north of the Corvallis, Oregon, Sewage Treatment Plant. The unit consists of two cells, each 1.07 acres in surface area. Liquid depth can be adjusted. However, all research to date has been conducted at a 3-foot depth. Dikes enclosing the unit are 8 feet across the top and have a side slope of 2 horizontal to 1 vertical. Raw sewage can be discharged into the center of each cell through a 6-inch fiber pipeline, or the cells can be operated in series. Outlets from each cell are at the south dike and discharge into a drainage ditch. Control facilities permit loading the two cells at different rates under the same environmental conditions or series loading. Permanent stations (see Fig. 1) for studying sludge accumulations, bacteriological conditions, and other tests are referenced by poles and signs to permit comparative studies over a period of time. The cells are enclosed by a 5-strand barbed wire fence and suitable signs (see Fig. 2), indicating the nature of the study and warning the public as to the lagoon contents are displayed on the fence. The lagoon effluent enters an outfall sewer within the fenced area that discharges to the Willamette River. A parking lot, walkways, analysis shelter, docks, and two boats serve as support facilities. Five small cells, each 200 square feet in surface area, have been constructed adjacent to the south dike of the lagoon to provide for studies on the effect of chlorination on lagoon operation, soil sealing, and a series operation with extended detention periods.

Control Equipment

Sewage is pumped to the lagoon site by a 350-gpm sewage pump. Control of total quantity is accomplished by adjusting pumping time with a time clock system. The pump intake is on the return elbow of the sewage plant comminuter; hence, a comminuted raw sewage is obtained. The

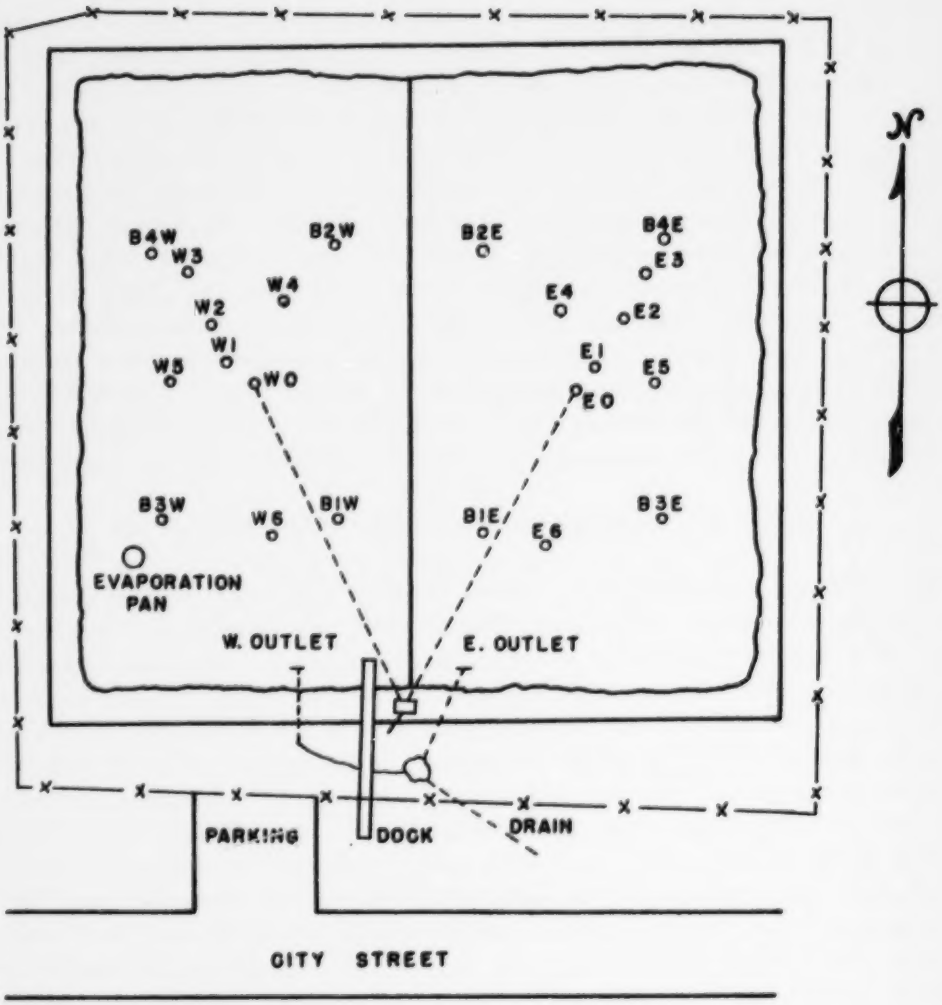

Figure 1. Experimental Lagoon Plan

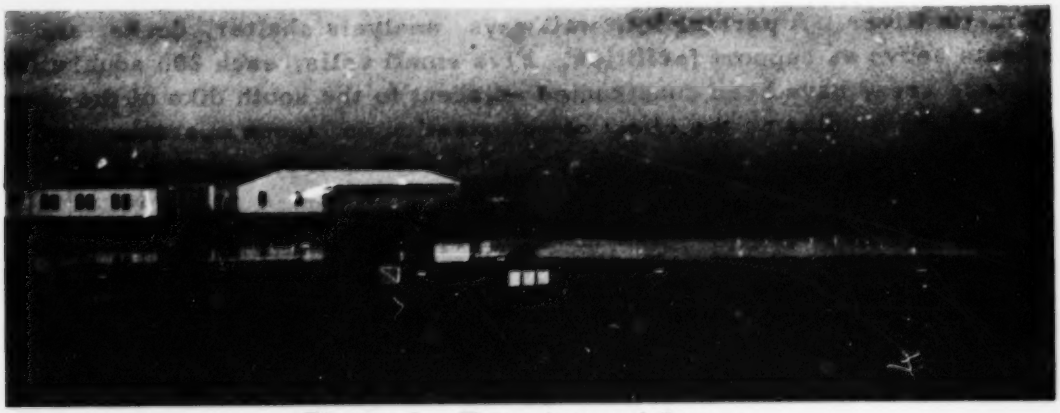

Figure 2. Experimental Lagoon

discharge piping to the lagoon consists of two 4-inch steel pipelines that terminate in a flow measurement box equipped with a 7-day liquid level recorder to provide for continuous monitoring of the system. A water wheel on the measurement box drives a sample compositing mechanism that operates at all times the pump is running in order that a representative sample is obtained. During earlier phases of this research, samples were composited by existing facilities at the Corvallis Sewage Treatment Plant. Flow from the control box may be divided between the cells or diverted to one cell for series operation.

Climatological Measurement

Since lagoon performance is closely related to climatological conditions, rather complete weather data are obtained. Data on temperature and precipitation are obtained from Oregon State University Farm Crops Department. Solar energy measurements are made with an Eppley pyrheliometer equipped for continuous recording which is located 3 miles southeast of the experimental lagoon. Results of the solar energy measurement are recorded in terms of gram-calories per square centimeter. (A gram calorie per square centimeter per day is equivalent to 1 langley/day.)

Net precipitation-evaporation measurements are made in an evaporation pan 4 feet in diameter and 3.5 feet deep, sunk in the lagoon and equipped with a Stevens hook gage. The pan is silver in color. No significant temperature differences have been found to exist between it and the lagoon. A summary of climatological data in terms of monthly averages is given in Table 1.

Laboratory

Major testing is accomplished in the Sanitary Engineering laboratory of the Department of Civil Engineering. Facilities of the Department of Bacteriology and the City of Corvallis are used as needed. A shelter is provided at the lagoon site and serves as a laboratory for analyses that need to be made immediately upon collection.

Diurnal variations in solar radiation affect lagoon performance. A comparison of variation throughout the day expressed as an average is shown in Fig. 3 for summer and winter months.

Table 1. Weather Data Summary

	Air temperature, °F**			Precip**	Solar energy*	Evap**
	Max	Min	Mean	in.	gm cal/cm^2/day	in.
January	45.3	32.5	39.0	6.42	109	-
February	50.5	35.1	42.8	5.10	132	-
March	55.3	37.0	46.2	4.06	164	-
April	62.3	40.5	51.4	2.10	395	2.55
May	68.8	44.9	56.9	1.85	454	4.05
June	73.4	49.3	61.4	1.29	685	4.64
July	81.3	51.9	66.7	0.32	697	4.35
August	80.9	51.4	66.2	0.38	524	6.00
September	76.8	48.8	62.8	1.30	406	3.94
October	64.7	43.4	54.3	3.53	234	2.05
November	53.1	37.5	45.4	5.44	128	-
December	48.1	35.7	41.7	6.15	91	-

* Data available.

**Approx 25-year average.

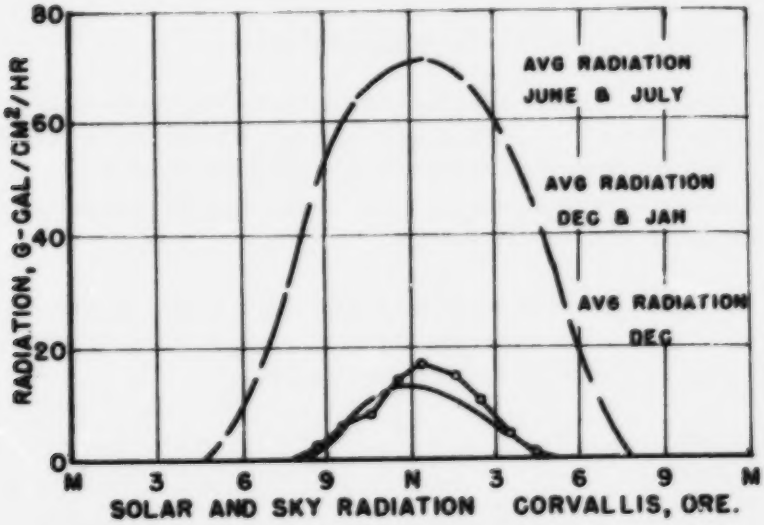

Figure 3. Durnal Variation in Solar Radiation

PRELIMINARY RESULTS

Loading Data

Experimental results, discussed in this report, were obtained from studies of the waste water lagoon that included two phases. "Phase I" consisted of studies on parallel loading, and "Phase II" covers studies on series loading.

The primary measures of loading in this study were flow, 5-day biochemical oxygen demand (BOD), and suspended solids (SS). Other tests have been included but not on a routine basis.

Since 5-day BOD is a most widely accepted parameter for sewage strength, this measure was used as the principal loading criterion. In order to establish acceptable loading values, 50 and 100 pounds of 5-day BOD per acre per day were selected as loading rates for the east and west cells of the experimental lagoon as the initial target values for the first phase of the study. Variations in strength caused some departures from these values.

Figure 4 gives average monthly loadings in terms of pounds of 5-day BOD per acre per day. Difficulty in adjusting flow rates to sewage strength prevented exact loadings. This was not considered a serious problem, however, because of the compositing effect of the lagoon.

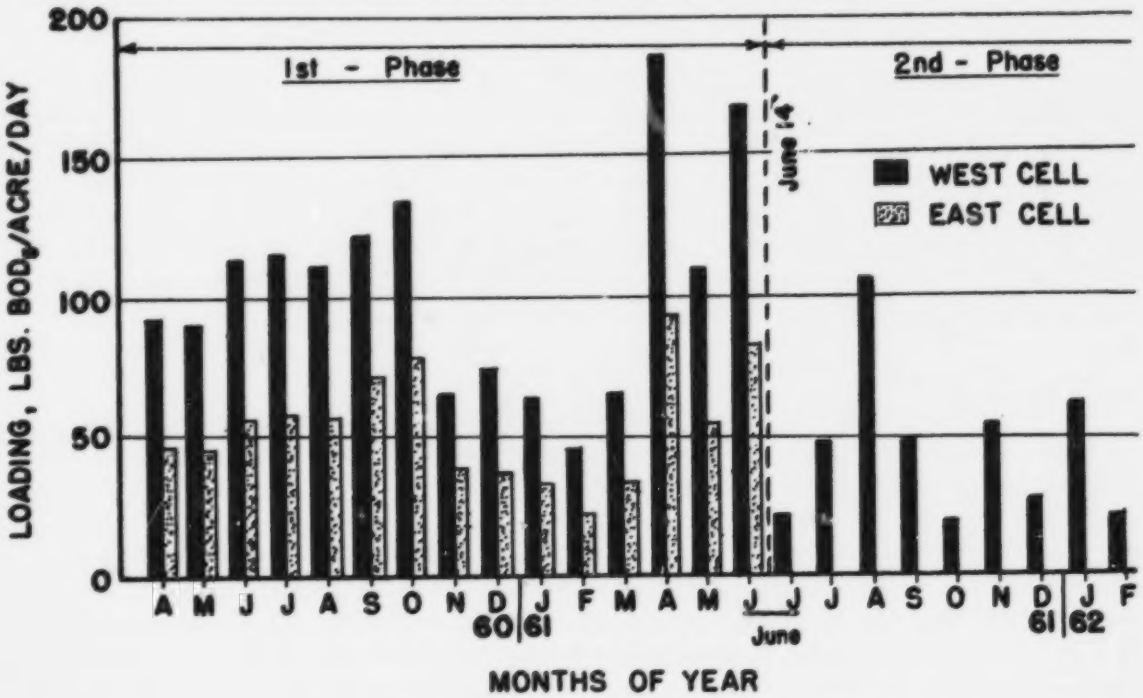

Figure 4. Average Loading Rates - BOD

During the first phase of the study, failure in the west cell occurred in September and again in October and November 1960. This failure was accompanied with low to zero dissolved oxygen, floating sludge, very objectionable odors, low pH, and poor removal efficiency. Periods of recovery were permitted during the above months, hence the values shown represent averages during days of loading rather than true monthly averages.

The principal cause of this failure was large loadings of highly colored beet cannery wastes. The increased light extinction reduced algal activity to below the critical level, and dissolved oxygen production did not keep pace with requirements for aerobic decomposition, hence septic conditions were established.

The east cell, loaded at one-half the rate of the west cell, continued to function satisfactorily without nuisance during this same critical period.

In early February 1961, the color in both cells turned to gray green and a red ring of tubifex formed at the edges of both cells. Both cells had the appearance of impending failure. Flood waters during that month, however, inundated both cells resulting in a nearly complete change of conditions in the two cells. After the flood, pumping was set at a rate to again attempt to establish conditions similar to those that existed before the flood. Even though high loadings were retained through the months of March, April, and May 1961, aerobic conditions and satisfactory appearance remained.

In June 1961, the loading pattern was changed to that of series operation. The west cell was loaded as the primary cell with raw sewage and the east cell was loaded with effluent from the west cell. The loading rate established as an acceptable value for the west cell was 60 pounds of 5-day BOD per acre per day. Variation in strength of the sewage due to a change in an industrial operation caused more difficulty in adjusting flows for loading than had been experienced in the previous year's run. Series operation information is shown in Fig. 4 in terms of pounds of 5-day BOD per acre per day.

Failure of the primary (west) cell occurred in September 1961. Cause of the failure and condition of the cell was similar to that condition previously described for September 1960.

To re-establish aerobic conditions in the west cell, the primary and secondary cell loading pattern was reversed. Raw sewage was fed into the east cell and the west cell was used as the secondary. This hastened the re-establishment of aerobic conditions in the west cell by not only reducing the loading, but by introducing water to the west cell from the east cell, which was high in algal, oxygen-producing forms. After a short period of recovery,

the loading pattern was reversed so the west cell was again the primary cell.

Suspended solids (SS) determinations were made and monthly averages in pounds of SS per acre per day are presented in Fig. 5.

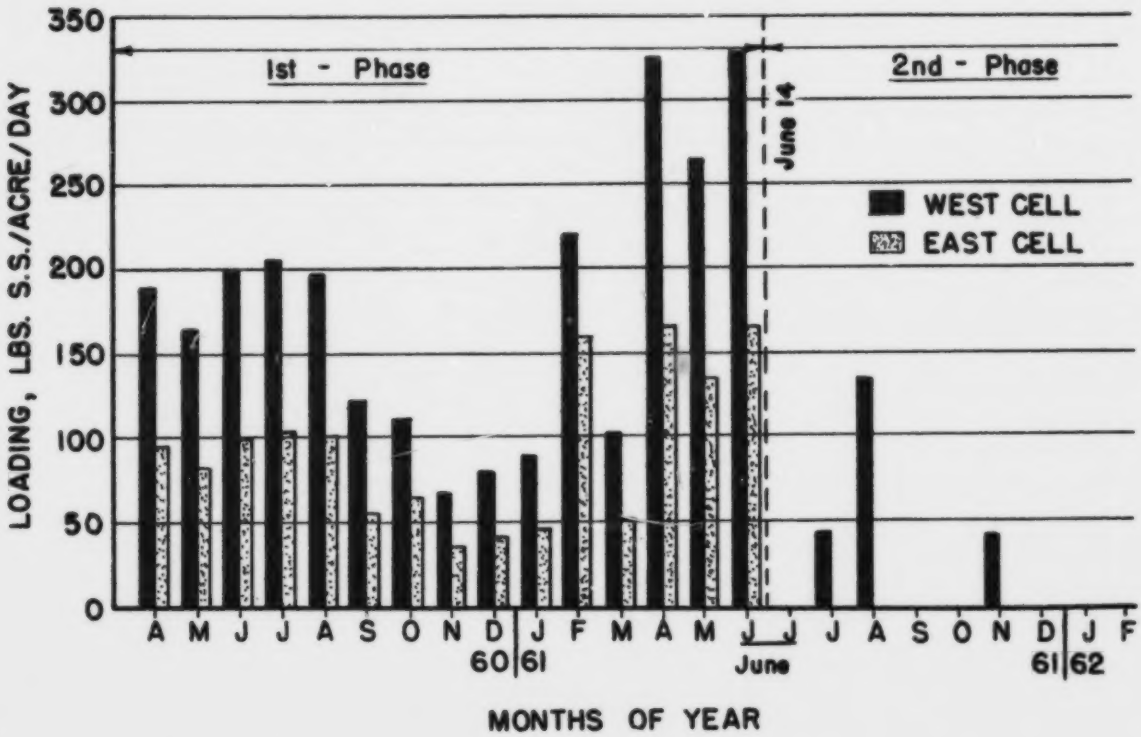

Figure 5. Average Suspended Solids Loading

SS determinations on the east (secondary) cell influent during the second phase of the study were not continued after preliminary determinations indicated that a significant part of suspended solids was contributed by the aquatic forms in the influent.

Studies of bottom sludge accumulation as related to suspended solids are being conducted and are covered in a separate section of this report.

Since the expression of loading criteria for this study is 5-day BOD per acre per day, flows and detention times are a function of BOD of the influent. For this reason, detention times varied as changes in BOD were encountered. Detention times for the cells during both phases of the study were calculated and are presented in Table 2. Attention is called to the values listed for the west cell during the months of September, October, November 1960, and September 1961. Values during failure and recovery periods are not true monthly averages for reasons previously discussed.

Table 2. Volumetric Loading

	Phase 1. Parallel Loading			
	West cell		East cell	
	Detention days	Days loaded	Detention days	Days loaded
April	18.6	26	37.2	26
May	18.6	31	37.2	31
June	18.6	30	37.2	30
July	20.2	31	40.5	31
August	21.2	31	42.0	31
September	130.0*	6	43.9	30
October	64.0*	17	43.9	31
November	103.0*	7	50.0	30
December	23.2	31	46.6	31
January	19.8	31	39.6	31
February	10.9*	24	21.8*	24
March	6.0	31	12.0	31
April	7.4	30	14.8	30
May	11.4	31	22.8	31
June 1-13	11.8	13	23.6	13
	Phase 2. Series Loading			
	Combined		West cell	East cell
	Detention days	Days loaded	Detention days	Detention days
June 14-30	41.0	17	20.5	20.5
July	31.2	31	15.6	15.6
August	21.0	31	10.5	10.5
September	60.6*	27	30.3	30.3
October	64.0	31	32.0	32.0
November	27.0	30	13.5	13.5
December	22.6	31	11.3	11.3
January	25.0*	27	12.5	12.5
February	18.7	28	9.4	9.4

*Loading not continuous

Quality of Effluent

Tests for an indication of the quality of effluent from the two cells of the lagoon used in this study included dissolved oxygen (DO), pH, BOD, transmittance of light, coliform density, chlorine demand, and others.

The results of dissolved oxygen determinations are presented as monthly averages in Fig. 6. The concentration varied from supersaturation during early spring and summer periods to zero at the point of failure. These reported averages for the first phase are from measurements taken at approximately 2:00 PM daily. Since DO concentration is maximum in the mid-afternoon, during the midafternoon the slope of the diurnal fluctuation curve (see Fig. 4) approaches zero. Two PM was chosen as the most probable time in a winter-summer operation for this maximum condition to occur.

Included in the dissolved oxygen averages of the west cell for the months of September, October, and November 1960, are DO taken during the period of recovery. This would account for the high concentrations immediately following times when failure has occurred.

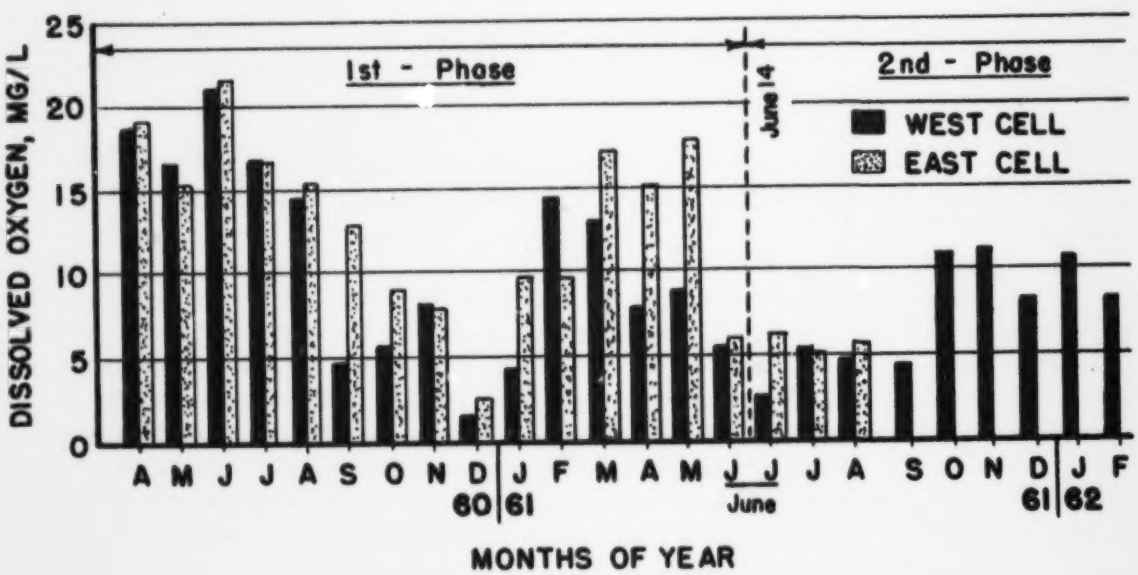

Figure 6. Dissolved Oxygen Averages

The results of dissolved oxygen determinations for phase 2 of the study are presented in Table 6. A comparison of the DO's (first and second phase) for corresponding summer months show the DO's for series loading to be lower. The time of sampling would account for the lower DO values.

During the second phase it was necessary to change the sampling point to a point where no refrigeration was available. To minimize the effect

of decomposition during the time of sample compositing, loading was changed to early morning. Loading samples and DO samples were picked up at approximately 9:00 AM. Although oxygen concentration changed during the day to the extent that comparison of DO in parallel and series operation was difficult, this was considered no great disadvantage.

Results so obtained are not to be construed as possessing great accuracy. The results, however, are indicative of the DO levels of the cells at the time of sampling. During the month of September 1961, failure in the west cell occurred and the series loading was reversed, as was previously explained. This reversal of flow accelerated the recovery to an aerobic condition.

A sampling depth of 6 inches below the surface and at the point of outlet to the receiving stream in each cell was used for routine measurements. The unmodified Winkler method was employed in determining DO values, and it was recognized that interfering elements and compounds were probably present in these samples being tested.

Dissolved oxygen values that have been determined as recorded in the appendix and summarized in Fig. 6, were not intended to be absolute values but merely one determination in a daily and hourly changing situation which indicated general condition. These data represent qualitative rather than quantitative determinations.

pH was determined for the effluent discharge from the two cells of the lagoon. The monthly median of pH and the pH range for each cell is presented in Table 3.

The quality of effluent in terms of percent of BOD removed is presented in the form of montly averages in Fig. 7. Efficiencies were calculated from 5-day, 20-degree BOD data from the raw influent and from the effluents as they were discharged to the receiving stream with no additional treatment. Efficiencies calculated on this basis for the first phase indicated a high degree of removal well above 80 percent during the periods of aerobic operation. An inspection of BOD data just prior to the failure and recovery period of the west cell in August 1960, and calculation of efficiencies, will show values as low as 23 percent.

Efficiencies for series operation were determined similarly to those described above. Attention is called to the low efficiencies calculated for the secondary (east) cell. Relatively little change took place in the BOD through the east cell. Because of the relatively small change of algal forms and loads in the primary and secondary effluent, low efficiencies should be expected.

Table 3 pH Data Summary

	West Cell		East Cell	
	Median	Range	Median	Range
*April, 1960	8.8	7.0-10.4	9.0	7.3-10.8
May	9.2	8.5-10.6	9.2	8.3-10.6
June	9.5	8.0-11.0	9.9	8.5-10.8
July	9.1	8.3-10.4	9.3	8.2-10.7
August	9.3	7.0-10.0	9.7	8.3-10.7
September	7.3	7.0- 9.5	7.2	7.0- 9.5
October	7.3	6.6- 9.4	8.7	7.1-10.2
November	7.1	7.1- 8.6	7.5	7.2- 8.5
December	6.8	6.5- 7.1	7.0	6.9- 7.4
January, 1961	7.1	6.2- 7.4	7.2	6.2- 8.4
February	7.3	6.9- 8.6	7.3	7.0- 8.1
March	7.6	7.6- 9.1	8.3	8.0- 9.2
April	7.4	7.3- 8.8	8.7	7.7- 9.3
May	7.5	7.4- 8.5	8.8	8.5- 9.5
June		7.4- 8.4		8.8- 8.9
**June	7.8	7.6- 7.8	8.6	8.4- 9.2
July	8.7	8.2- 9.3	8.8	8.7-10.0
August	8.8	7.6- 9.0	9.0	8.8- 9.7
September			7.2	7.2- 7.6
October			8.9	7.9- 9.5
November			8.3	7.3- 9.0
December			7.3	
January, 1962			8.3	7.7- 8.8
February			7.4	7.2- 8.1

*Phase 1 Parallel operation

**Phase 2 Series operation

Since the conventional BOD tests measure total oxygen respiration in the sample bottle during incubation, the values may have little bearing on the pollutional nature of lagoon effluent. Much of the material is in the form of living cells that would not affect the receiving stream in the manner they affect BOD measurement. The rather basic question of interpreting results remains for future study.

The nature of the materials causing BOD becomes critical, particularly in those cases where disinfection is required. Determination of BOD to include the algal cells was performed on seeded samples, both filtered and unfiltered. An inspection of the data in the appendix shows a

comparison of the untreated filtered and unfiltered effluents.

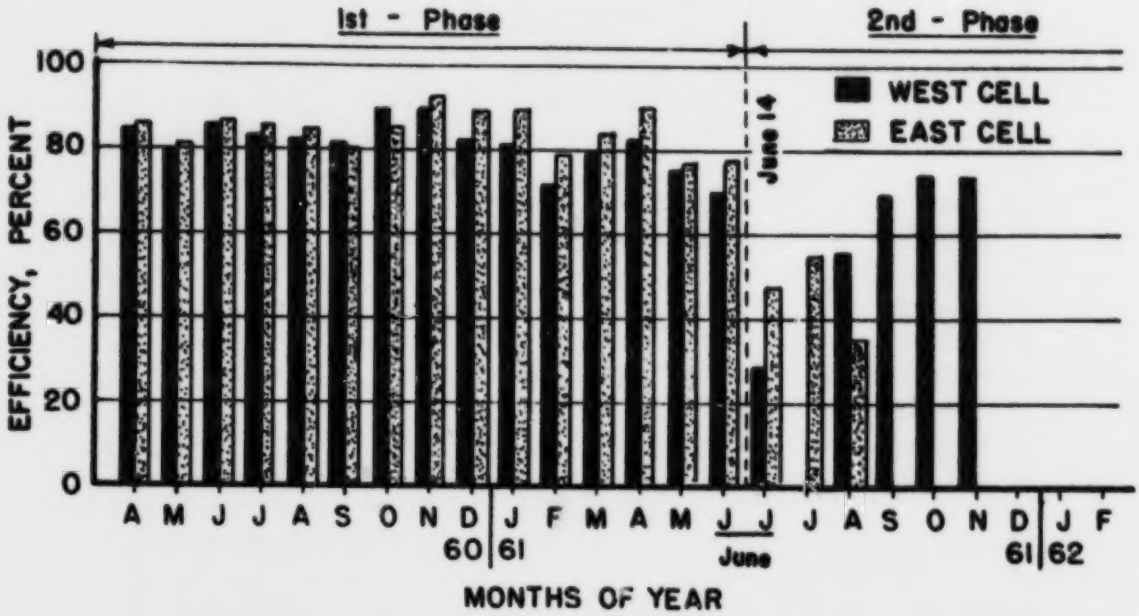

Figure 7. Average Efficiencies of BOD Removal

Heat killed unfiltered samples probably represent more nearly the true BOD load placed on the receiving stream when disinfection of the effluent is practiced. It is noted in most cases that the BOD for the heat killed unfiltered samples is higher than that of the untreated samples. In many instances the total load of BOD leaving an oxidation lagoon may be higher than that in the incoming raw sewage if disinfection is done on the effluent stream. Further discussion of this factor is presented in a later section.

Transmittancy determinations were made on raw samples of the influent and effluent for comparison purposes. These samples were placed in a centrifuge and run for 15 minutes at 3000 rpm. The centrifuge supernatant and the residue were then separated and transmittance determinations were made on the supernatant on a Beckman spectrophotometer at a wave length of 650 microns. Results of these determinations are presented in the appendix.

Values determined for transmittancy ranged from approximately 70 percent to 95 percent for the effluent from the two cells and the influent. No particular correlation is evident at this time of the study. The data are collected routinely, however, because they are felt to have bearing on critical light levels and oxygen production.

During the period from April to September 1960, the color of both cells was dark green, as associated with high algal activity. No offensive odors were detectable. This appearance was associated with an aerobic condition. In early September 1960, the west cell began changing from a green to a gray color. Algal counts dropped proportionately, and around the edges of the west cell a red ring of tubifex was observed. The change in aquatic life was punctuated by very objectionable odors and floating sludge, associated with an anaerobic condition. The loading of the west cell was discontinued to permit re-establishment of satisfactory aerobic conditions.

A recovery period of about 5 days was permitted, during which objectionable odors changed, algal activity increased, and the tubifex disappeared. Loading to the west cell was started before a complete recovery, however, because the failure cycle was experienced twice more in the following months. Through the winter months algal activity in the east cell was low and the color turned gray, but at no time was there any floating sludge or tubifex observed or objectionable odors detected.

In 1961, during the months of April, May, and until June, the color of both cells was dark green and no tubifex ring was evident in either cell, a condition that was associated with a satisfactory aerobic condition. During the second week of June, the color changed in the west cell to a slight brownish green, while the east cell remained a deep green color. Vigorous gas production was noted in both cells. As a result of the gas production, sludge floated to the top and covered approximately 15 percent of the surface area of the west cell (see Fig. 8).

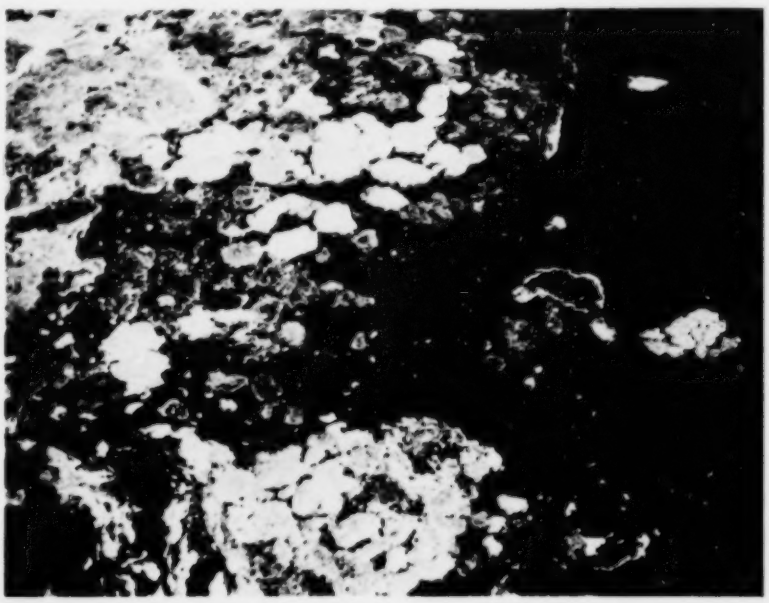

Figure 8. Floating Sludge

The absence of any wind, which would break up sludge blankets and allow the solids to settle, and the presence of warm, dry weather, caused the sludge to dry on the surface. There it remained for approximately three weeks.

A slight odor was detected issuing from the floating sludge, but at no time did the cells change color nor did the pH or DO of the effluent indicate anything but an aerobic condition. Even though the odors were detected, a greater nuisance existed in that the floating sludge blanket provided an excellent place for fly and mosquito larvae to hatch.

A shower, accompanied with a brisk wind, occurred about three weeks after the sludge first appeared. This combination broke up the sludge and caused it to settle.

The east cell, loaded at one-half the rate of the west cell, has operated satisfactorily throughout the initial test period. It is felt that the critical loading circumstances were bracketed in the initial test.

Foam caused by detergents has been observed at the outlets of the cells of the lagoon. Figure 9 shows this condition on a typical day. The free fall of the outlet causes sufficient turbulence to cause foam. Detergent survival through the process is a subject of current study.

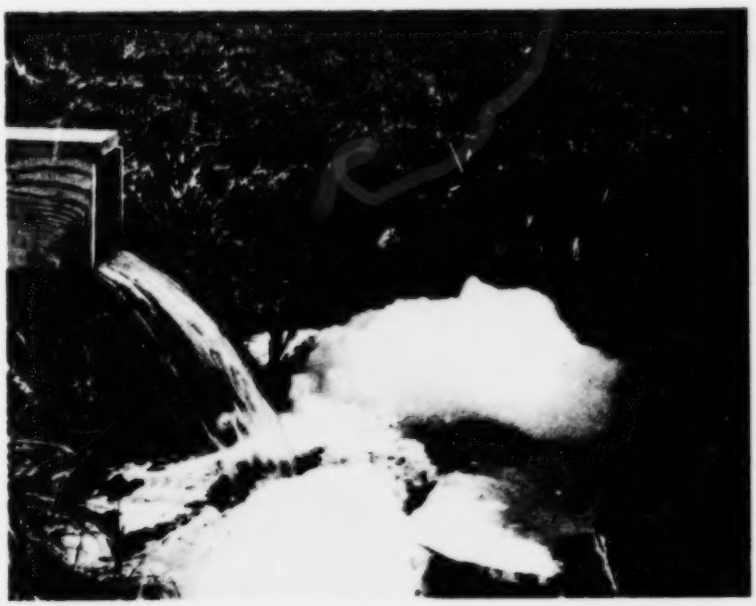

Figure 9. Foaming at Outlets

Bacteriological Studies

Bacteriological quality of the lagoon effluent is of particular importance in a maritime region. Since annual precipitation exceeds annual evaporation, a lagoon effluent must be disposed of by dilution into an existing water course, used for irrigation, or handled in some other satisfactory manner. In all cases the bacteriological quality must be considered. This quality will be quite variable, and is not only affected by bacterial specie, lagoon environment, and waste water quality, but also by the location of the inlet to the outlet, wind direction, lagoon short circuiting, and rate of hydraulic loading or detention time. As may be expected, the bacteriological quality of the lagoon effluent varies from day to day and within the time of any one day. More detailed investigations of these variations are the subject of current study.

Because of the limited research staff, bacteriological studies were limited to samples collected on selected days near 10:00 AM. These were analyzed for coliform density by the millipore filter technique. A 47 mm type H. A. filter, grid marked with 0.45 micron pore openings, was utilized, together with M-Endo Broth M. F. 0749-01 as produced by Difco laboratories. Manipulative technique employed was that listed in Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, 11th ed., American Public Health Association, et al, and was suggested by Mr. H. F. Clark, microbiologist with the U. S. Public Health Service at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio.

Results of bacteriological studies to date are given in Table 4 in terms of hundreds of bacteria per milliliter of effluent. To convert these figures to the standard MPN units of coliform organisms per 100 mls, multiply the given value by 10,000.

An examination of the bacteriological data shows that in most cases coliform organisms as an indicator of fecal contamination were less in the lagoon effluent than in the influent.

Short circuiting of the cells because of wind currents caused some variation of this pattern.

During the second phase of the study when the loading was in series there were usually fewer coliform organisms in the secondary effluent. Whether this reduction is due to the reduction of the solids load or due to a time lag is undeterminable from these data.

Table 4. Bacteriological Data

Date	Day of wk	Coliform bacteria per ml/100* Raw	West	East	Date	Day of wk	Coliform bacteria per ml/100 Raw	West	East
1960									
7-15	F	40	3.8	3.15	9-12	M	440	6.5	80
8- 3	W	70	10.2	4.2	9-14	W	210	-	9
8- 6	S	70	60	20.4	9-16	F	360	2.0	17.5
8- 8	M	350	29	7	9-21	W	110	1.7	18
8-10	W	700	24.6	26	10-28	F	160	12.0	1.3
8-12	F	1800	29	23	11-11	F	20	-	0.5
8-15	M	25	11.8	6	12-19	M	50	2.4	0.45
8-17	W	170	36	15	12-30	F	770	14	0.6
8-24	W	280	35	10	1961				
8-29	M	1600	38	79	1- 7	S	30	22	2.4
8-31	W	700	18	6.5	1-14	S	30	2.4	3.2
					1-28	S	25	0.15	0.15
					2-18	S	8.0	0.88	0.83
					3- 4	S	2.0	0.7	0.2
					3-11	S	13.5	0.55	0.2
					3-25	S	1.0	3.0	0.1
					4- 1	S	15	0.6	0.01
					4-25	T	50	0.5	0.2
					4-29	S	3	0.5	0.03
					5- 6	S	15	0.44	0.40
					5-13	S	2.5	0.08	0.05
					**				
					6-14	W	7300	13	7.5
					6-21	W	350	15	3
					7- 5	W	130	56	3
					7-19	W	2000	280	30
					7-26	W	3800	25	31
					8- 2	W	300	40	15
					8- 9	W	7000	70	1
					8-16	W	80	0.9	2

*Coliform/ml = reported figure × 100
Coliform/100 ml = reported figure × 10,000

**Series loading West to East cell

Disinfection Requirements

The percentage reduction of coliform organisms through the oxidation lagoon is rather large. The bacteriological quality of the effluent, however, indicates that based on current standards, disinfection may be required under some circumstances. Merits of disinfection and the problems of after growth are recognized. Since these are the subject of current studies at the Robert A. Taft Sanitary Engineering Center, no attempt has been made to interpret disinfection needs in this report.

Chlorine requirements for disinfection were studied on the basis of the required dosage to obtain a total chlorine residual of 0.5 mg/L after 30 minutes of contact time. This was accomplished by dosing samples with various amounts of chlorine so as to bracket the requirement values. The residual in each sample was determined by the orthotolodine test. Table 5 is a listing of data so determined.

No attempt has been made to correlate the chlorine requirement with various related parameters. It should be noted that the chlorine demand of the effluent is at times greater than that for raw sewage. Your attention is directed to the section entitled "Quality of Effluent" for consideration of the major problem involved in effluent chlorination. Algae killed coincident to chlorination contribute a significant source of dead and readily decomposable organic matter to the effluent stream. In many cases, the quality of effluent from a BOD standpoint may be equivalent to raw sewage. This factor indicates that either closely controlled chlorination of the influent so as not to affect lagoon operation or removal of algae prior to effluent chlorination is required if disinfection is necessary.

Reaeration Mechanics

Reaeration at the lagoon surface by transfer of oxygen across the liquid-air interface is of considerable importance in oxidation lagoons. While the principal source of dissolved oxygen is from photosynthetic production by algae, this mechanism depends upon maintenance of an adequate plankton population. Several factors may severely limit or destroy phytoplankton growth. These include toxic materials, overloading, large blooms of rotifers or crustacea, exhaustion of nutrients, and other environmental changes unsuited to good algae production. A major source of trouble has been encountered in the experimental oxidation lagoon during periods of highly colored beet canning wastes, which severely reduce the light extinction coefficient and, hence, algal activity. During any period of low oxygen production by algae, reaeration from the surface is the principal source of oxygen.

The basic approach used to study surface reaeration has been to apply the gas transfer equation.

Table 5. Disinfection Requirements

Date	Cl_2 requirement mg/L to 0.5 mg/L residual: Raw influent	West effluent	East effluent
*1960			
8- 1	6.0	6.0	6.0
8- 8	5.0	6.0	9.0
8-15	10.0	6.0	6.0
8-19	4.0	5.0	8.0
8-22	7.5	7.0	7.5
8-29	-	13.5	13.5
8-31	13.0	10.5	16.0
9- 5	6.0	6.0	12.0
9-12	-	6.0	8.4
9-19	9.0	3.0	9.0
10-28	2.0	3.0	3.0
12-19	2.0	4.0	2.0
12-24	5.0	2.8	2.0
1961			
1- 7	3.0	2.0	2.0
1-14	3.0	2.0	2.0
2-14	7.0	2.5	2.0
3- 4	-	3.0	2.0
3-11	2.0	1.5	1.5
3-18	1.0	1.0	2.0
3-25	1.4	2.0	3.5
4- 1	2.0	1.5	2.5
4- 8	2.5	2.5	2.5
4-15	2.0	2.0	2.5
4-22	3.5	5.0	5.0
4-29	2.5	2.5	3.0
5- 6	2.5	3.0	2.5
5-13	2.0	3.0	2.5
** 6-14	16.0	4.0	4.0
6-21	1.4	2.5	2.4
6-28	2.5	3.0	3.5
7- 5	4.0	4.5	4.0
7-12	3.0	7.0	8.0
7-19	4.5	3.0	12.0
7-26	2.5	6.0	7.0
8- 2	5	9	7
8- 9	4	3	10
8-16	3	3	6
8-23	7	4	4

*Phase 1 Parallel operation

**Phase 2 Series operation

$$dD/dt = -K_2D$$

where D is oxygen deficit at the observed temperature or the difference between the saturation value for dissolved oxygen at that temperature and the actual concentration of dissolved oxygen present. dD/dt is the rate of change in deficit with time. Since dD is proportional to change in dissolved oxygen, d(DO), the equation may be written in terms of weight of oxygen, dw, as uptake in pounds of oxygen per surface acre per 24-hour period for the 3-foot lagoon.

$$dw = \frac{d(DO)(43,560)(62.4)(3)}{1,000,000}$$

$$dw_{lb} = d(DO) \times 8.15$$

The equation then becomes

$$\frac{dw}{dt} = \frac{d(DO)\ 8.15}{dt} = K_2D$$

if dt is in hours, K_2 has the units of reciprocal hours and the total uptake in terms of pounds of dissolved oxygen transferred per surface acre per day at steady state conditions may be calculated by

$$lb/day = K_2D \times 24$$

Since oxygen transfer is affected primarily by mixing within the lagoon, surface winds, and condition of the surface, the initial research approach has been to describe total mass transfer. Several light cells consisting of a clear plastic shell and a surface cover were constructed for placement in the lagoon. Figure 10 is an illustrative sketch of the experimental apparatus.

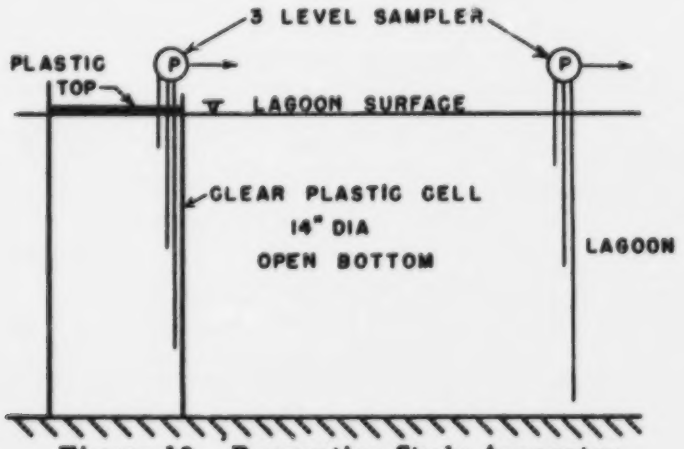

Figure 10. Reaeration Study Apparatus

The cell is placed in the lagoon at time zero; selected when the oxygen content in the lagoon is below saturation. Samples are taken at the surface, mid-depth, and near the bottom by a sampling pump to determine the true average dissolved oxygen in each system. At dt time later (normally 4 to 6 hours), samples are again taken to determine the oxygen present. Two curves are thus developed as illustrated in Figure 11.

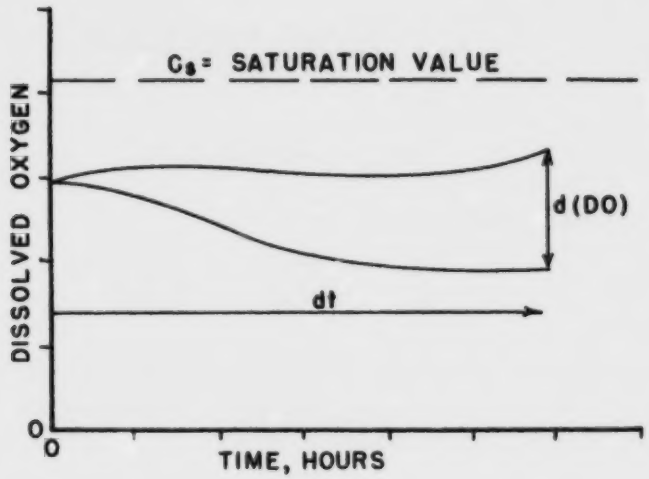

Figure 11. Oxygenation Curves - Lagoon vs Test Cell

Separation of the two curves is an indirect measurement of oxygen supplied from surface sources. While this method is somewhat cumbersome and subject to experimental errors, it has proved feasible. Additional work is being done on improvement of method and elimination of sources of error. Typical data obtained by this approach and their analyses are given in Table 6.

Table 6. Typical Reaeration Data

Time	Lagoon DO mg/L	Clear cell DO mg/L	Temp °C	Deficit "D" mg/L	$\frac{d(DO)}{dt}$	$\frac{dw}{dt}$	Kr
0	2.65	2.63	3	10.8			
					0.184	1.48	0.143
6	3.05	1.95	5	9.8			
					0.240	1.94	0.206
12	3.80	1.25	5	9.0			

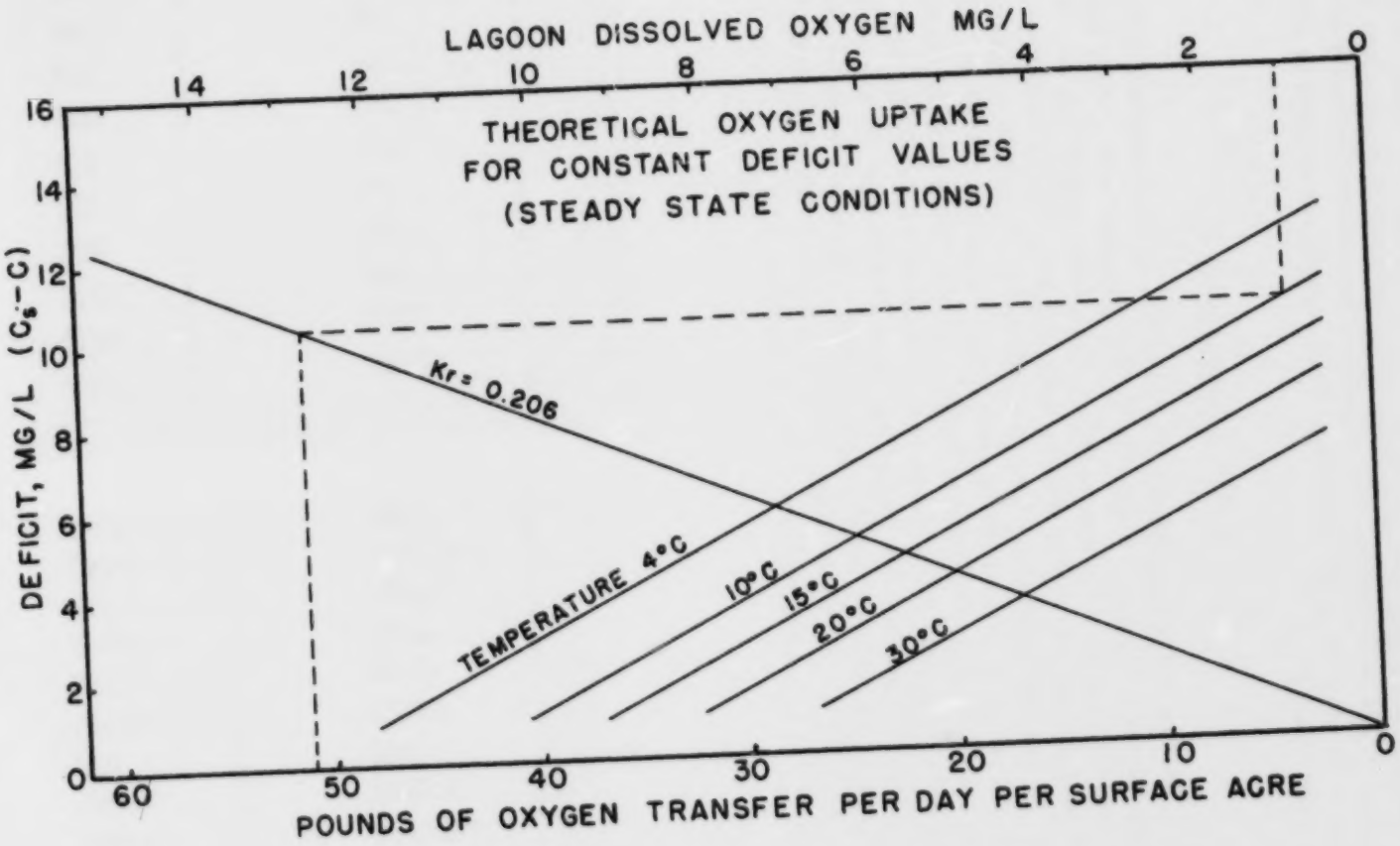

Figure 12. Reaeration Rate - Multicorrelation Graph

Values of Kr determined by this method have a range of 0.039 to 2.3, with a median value of 0.206. For convenience, a multicorrelation chart is shown in Fig. 12, giving the pounds of oxygen that may be transferred per surface acre per day at steady state conditions of constant deficit. The value of 0.206 is tentative and subject to review on the basis of future investigation. It may be seen, however, that significant oxygen is obtained from surface sources.

Sludge Accumulation

Sludge accumulation and distribution is an important consideration in oxidation lagoon criteria. Since the sludge blanket is in a constant state of change, single samples from one location have little significance. A program of determining change in sludge depth, composition, and distribution has been undertaken in the lagoon study. Core samples are collected in plastic sample tubes 1.25 inches in diameter from permanent sampling stations. These are analyzed for sludge composition and depth. Table 7 is a partial tabulation of the limited data available from these tests. Figure 13, showing typical sludge samples, illustrates the sampling tubes and sludge varations at the several sampling points and for the dates listed. Sample numbers are referenced to stations shown on Fig. 2, and to sample identification; i.e., sample L10, B3W is sample number L10 at location B3W.

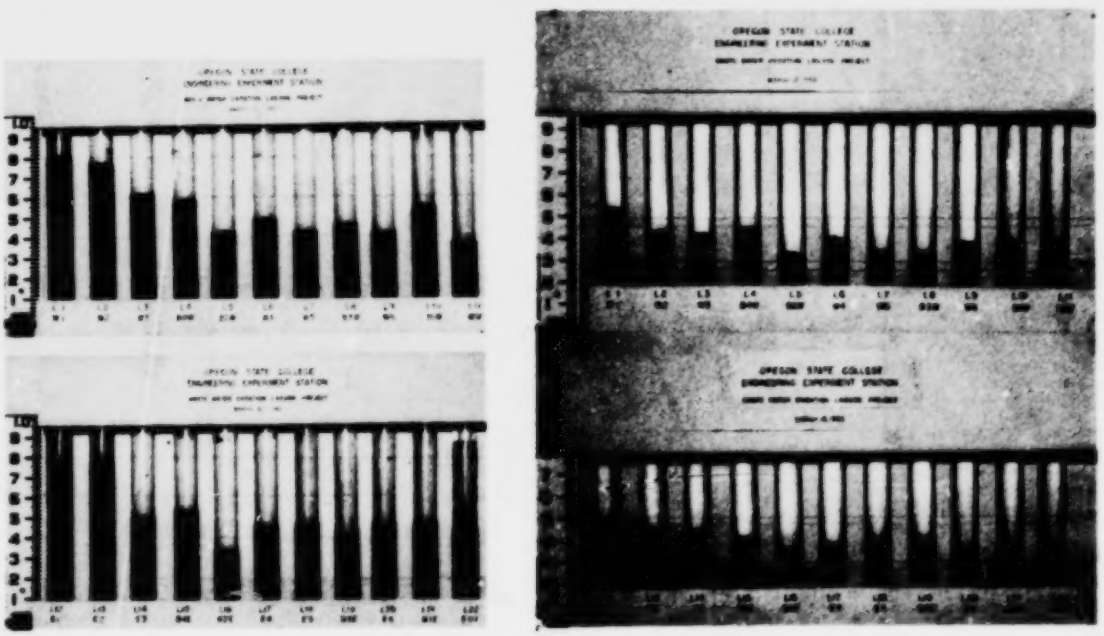

Figure 13. Bottom Sludge Samples

Table 7. Sludge Accumulation

West cell				East cell			
Location	Depth ft	$\frac{lb}{2}$ ft	% vol.	Location	Depth ft	$\frac{lb}{2}$ ft	% vol.
Data from samples taken March 21, 1961							
W1	0.61	3.90	32	E1	0.72	3.82	54
W2	0.57	2.89	33	E2	0.55	1.95	41
W3	0.42	1.69	32	E3	0.30	1.08	35
B4W	0.39	1.67	30	B4E	0.33	1.42	37
B2W	0.23	1.07	31	B2E	0.15	1.56	22
W4	0.30	1.38	28	E4	0.25	0.89	35
W5	0.23	1.07	29	E5	0.27	1.31	33
B3W	0.25	1.03	28	B3E	0.22	0.92	32
W6	0.22	0.76	29	E6	0.26	1.88	22
B1W	0.35	1.90	25	B1E	0.26	2.02	22
W0F	0.16	1.70	13	E0F	0.24	3.56	10
Data from samples taken March 10, 1962							
W1	0.34	5.17	11.7	E1	0.24	5.0743	16.9
W2	0.23	1.10	47.5	E2	0.24	1.14	29.6
W3	0.23	1.50	37.0	E3	0.24	0.94	28.6
B4W	0.24	0.66	26.7	B4E	0.20	1.05	24.4
B2W	0.13	1.44	29.9	B2E	0.16	0.26	34.3
W4	0.20	0.80	32.5	E4	0.18	1.25	46.1
W5	0.15	0.60	27.6	E5	0.14	0.63	27.1
B3W	0.14	0.63	26.3	B3E	0.19	0.51	33.4
W6	0.18	0.87	22.1	E6	0.15	0.61	37.0
B1W	0.18	0.68	26.3	B1E	0.15	1.40	30.0
W0F	0.18	1.44	19.5	E0F	0.17	0.50	24.4

lb/ft^2 = pounds of sludge per sq ft of bottom
percent fixed = 100 - percent volatile

Oxygen Production

Oxygen relationships are of importance in the experimental lagoon study because production of oxygen by algae is the principal source of oxygen available for reaeration. While detailed studies of the biological mechanisms have been made by other investigators, certain tests have been conducted in order to determine the effect of the various conditions characteristic of a maritime climate. Oxygen production in the lagoon is affected primarily by solar energy incident to the lagoon. However, algae specie, density of algal cells, temperature, and quality of the wastes in the lagoon also have an effect.

Interpretation of dissolved oxygen content in the lagoon at any time becomes impossible without considering the diurnal variation.

Figure 14 shows the oxygen variation on July 16, 1959, and is typical of a bright, summer day with solar energy in the range of 570 grams calories/cm^2 per day. It is of interest to note that the point of highest concentration varies with the time of year. For this reason, a procedure of measuring the dissolved oxygen at 2:00 PM has been adopted for routine work. Figure 3 gives the variation in solar energy for a day's period as averaged for the summer and winter months. The magnitude of oxygen variations has been found to be somewhat similar to the curves shown.

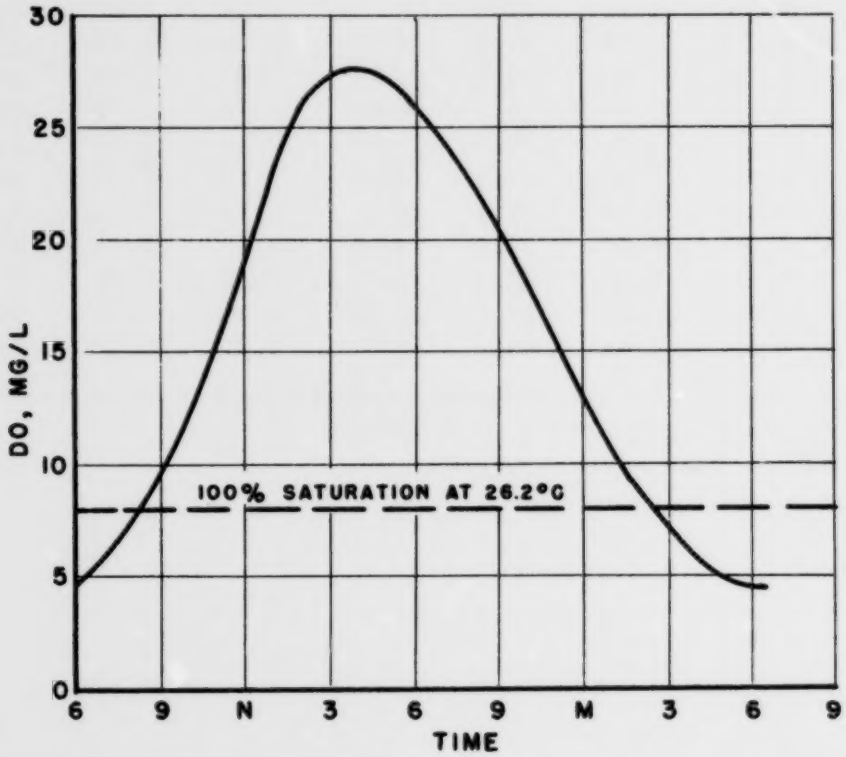

Figure 14. Diurnal Oxygen Variation at Lagoon Surface

Production of oxygen was determined by the standard dark-light bottle test. Figure 15 gives the results of an analysis of variation in oxygen production with depth on January 2, 1959, with a light energy of 177 gram calories/cm^2, temperature 8.7°C, wind 1.50 mph-SW, and precipitation 0.08 inch. Plankton present on that date in terms of ppm by wet volume were chlomydomonas 1-2 ppm, and scenedesmus amatus 7.2 ppm. It will be noted that 65 percent of the oxygen production occurred in the first 12 inches of depth. Justification of greater depths must therefore be based largely upon sludge storage and aquatic weed control.

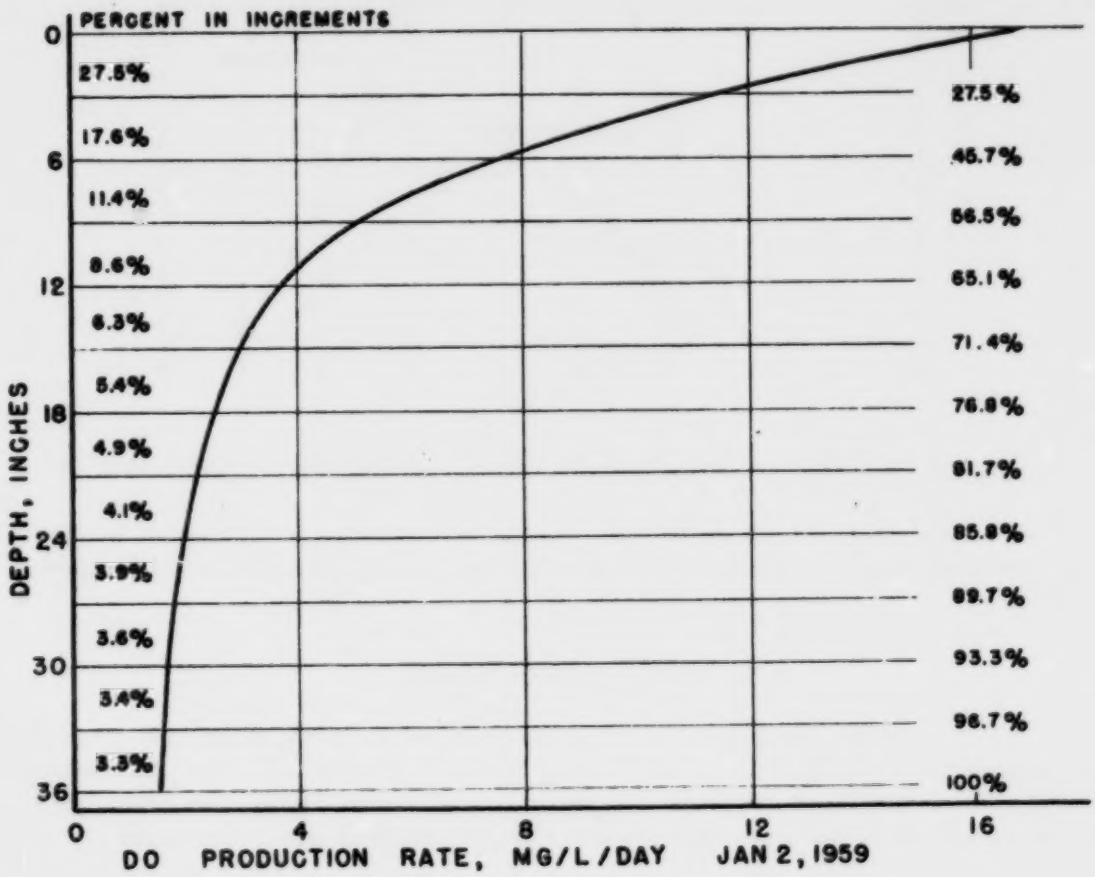

Figure 15. Oxygen Production vs Depth

Oxygen production in other depth increments and its variation throughout the day is shown by Figure 16. It again will be noted the significant production occurs in the top layer.

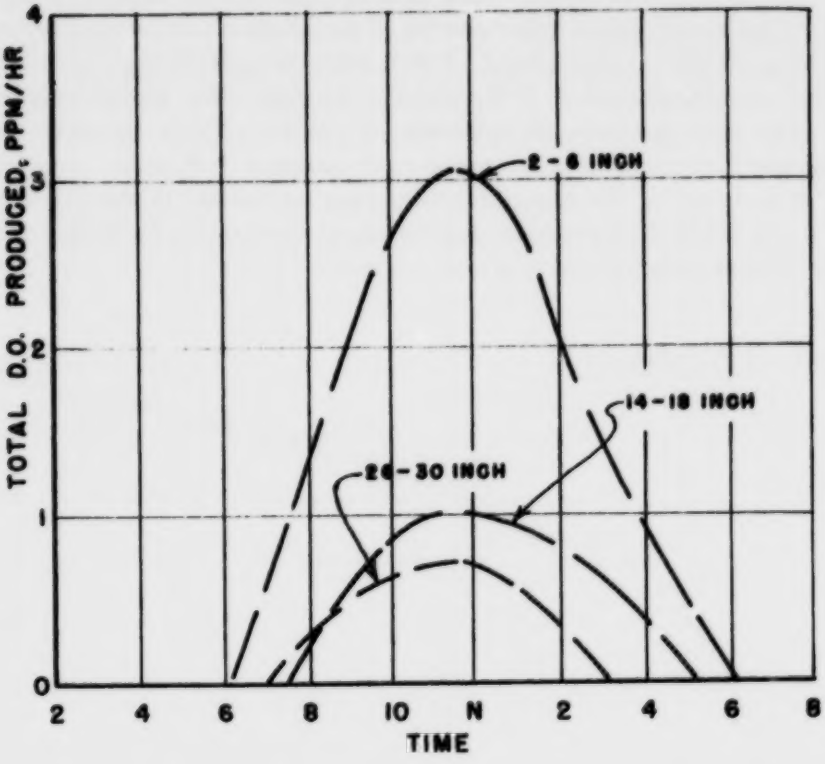

Figure 16. Diurnal Oxygen Production at Indicated Depths - Dec 23

Studies of light extinction versus waste color are planned to consider the important question of how waste color variations affect oxygen production.

Plankton Enumeration

Because algal specie and number are important to oxygen production in an oxidation lagoon, an effort was made to identify the most prevalent specie and to count and measure the volume of plankton in the two cells. Attention is called to the appendix for the results of these determinations.

Samples were collected from 6 inches below the surface at the point of discharge of the two cells and a specie determination and count of the phytoplankton was made under a 100-power micorscope with the aid of a nannoplankton counting slide. Portions of these same samples were then placed in a centrifuge and turned at 3000 rpm for 15 minutes. The residue was then measured and recorded as solid volume ml/100 ml. Typical species are recorded photographically as an interest item. Figure 17 illustrates a typical population.

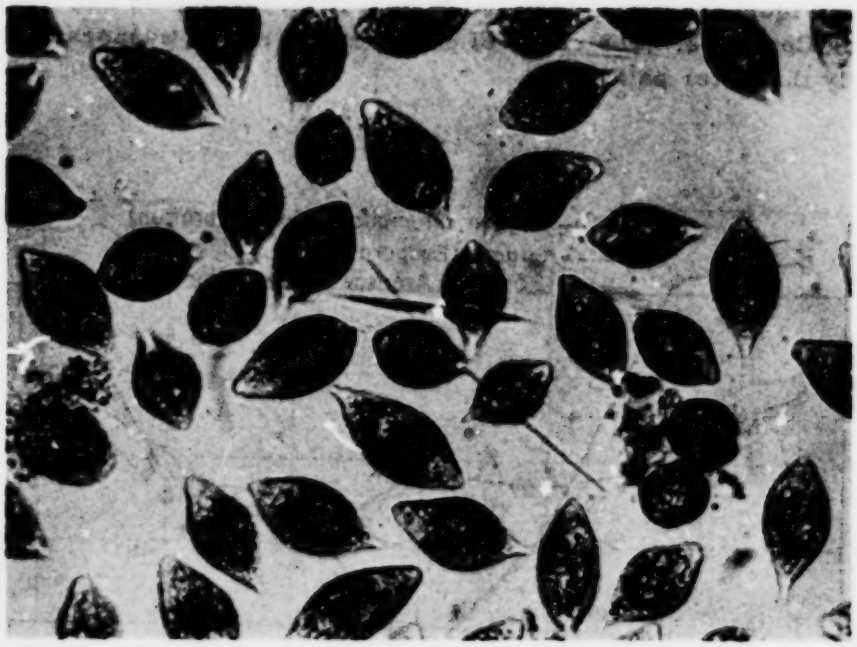

Figure 17. Typical Plankton Population

Water Balance

A significant portion of the waste water entering a lagoon is discharged to the atmosphere in the form of water vapor. An examination of the net precipitation minus evaporation for the summer months as determined from pan studies yields the data in Table 8. Evaporation data have been converted to equivalent people per surface acre on the basis of 100 gallons per capita per day, or 3000 gallons per capita per month.

Table 8. Water Balance Data

Month	Precipitation-evaporation inches	gallons	Equivalent persons/acre
June	- 5.59	151,729	50.3
July	- 8.94	242,738	80.8
August	- 5.00	135,760	48.5
September	- 4.29	121,912	40.4
4	24.02	652,139	220.0

Figure 18 gives evaporation data from the lagoon and the 25-year average for Corvallis. The curve of precipitation minus evaporation illustrates most nearly the water balance.

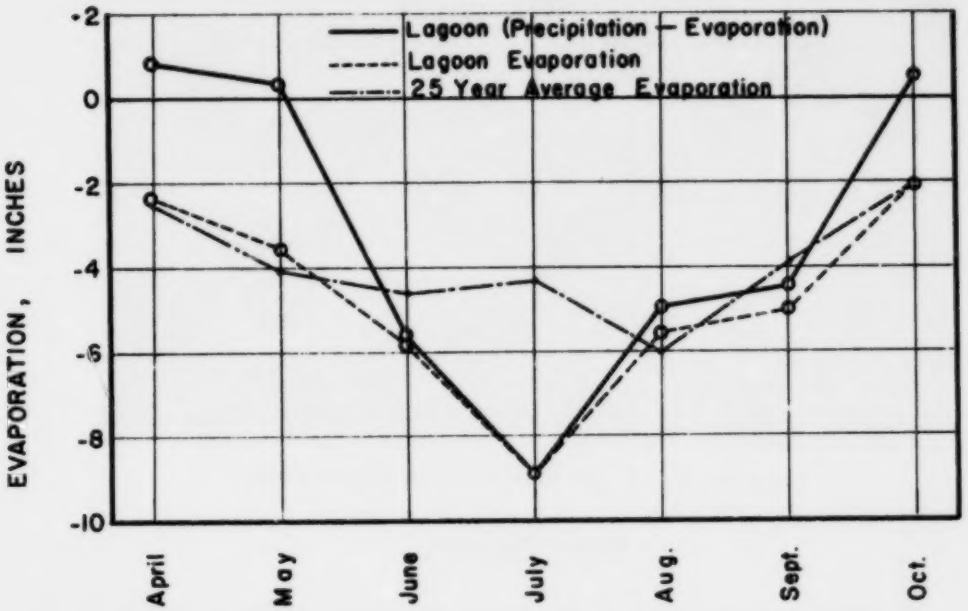

Figure 18. Water Balance

The volume of waste removed by the evaporation mechanism suggests development of data to rely on evaporation plus storage during critical summer months in lieu of discharge effluent. This may be of particular advantage when disinfection is required. On the basis of 3000 gallons/person per month, a contribution of 0.00797 acre feet per month is made by each person. This corresponds to a figure of 125.5 person months per acre foot.

Since inflow-discharge = change in storage, it follows that a lagoon designed with variable depth might store 2 to 3 feet of water during critical summer months. A schedule of storage plus evaporation might be arranged as shown in Table 9 to prevent discharge during low stream flow summer periods.

A multiple level outlet, such that the lagoon could be operated at 2.0-foot depth in late spring and a high water outlet at 4.25 feet, would accomplish this storage benefit of serving a population of 125 persons per surface acre at 100 gallons/capita/day without discharging to the stream.

Table 9. Suggested Operating Schedule

Month	Reliable evaporation in.	Evaporation equivalent population	Storage ft	Storage equiv pop.	Total pop./acre
June	5.59	50	0.60	75	125
July	8.94	80	0.36	45	125
August	5.00	49	0.60	76	125
September	4.49	40	0.68	85	125
		Total storage	2.24		

Mosquito Control

Ponds and lagoons many times provide a breeding place for mosquitoes. Therefore, mosquito control was considered in this study. This was accomplished by the control of aquatic weeds, thus eliminating a harborage for larvae, and by planting in the lagoon a small fish that fed on mosquito larvae—Gambusia.

Aquatic weeds were controlled by holding the liquid level to approximately 3 feet and by cutting and spraying the weeds around the edges of the lagoon. This was effective, but mosquito larvae were still observed at the edges. The Gambusia, as shown in Fig. 19, were then planted in control vessels in and around the lagoon. No mosquito larvae were observed in the control vessels but there were many observed in and at the edges of the lagoon. The local mosquito control people sprayed the cells to rid them of mosquito nuisance. The spraying killed the Gambusia, and this, unfortunately, stopped the work of using the Gambusia as a means of controlling mosquitoes.

Figure 19. Gambusia

RECEIVING STREAM STUDIES

A study of the effect of waste water lagoon effluent upon a simulated receving stream was undertaken to assess the problems that might be introduced by chlorination of the lagoon effluent. Previous studies had indicated that disinfection of the effluent resulting in algal death caused an apparent increase in the BOD of the effluent; the magnitude of this increase being quite variable. Changes in this relationship, together with other physical-chemical relationships were the subject of the receiving stream study.

A simulated stream was constructed consisting of four channels with paddle wheels to recirculate water (see Fig. 20).

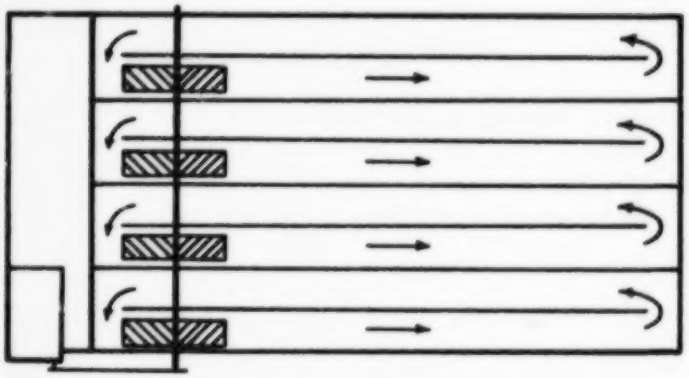

Figure 20. Flow Diagram of Simulated Stream

Since it was not practical to construct the model of a length sufficient to duplicate conditions, the approach consisted of considering each unit as a mass of water moving downstream in a river and subjected to conditions of light, temperature, and turbulence. A fluorescent lighting system was suspended over the simulated stream which produced an illumination of 550 foot candles at the water surface. Lights were operated on a time clock system. Temperature of the system was 14.5°C ± 1°C. Reaeration studies conducted by depressing oxygen values and calibrating uptake rates indicated the reaeration constant "K_2" for the system was 0.678/day.

Studies consisted of following physical-chemical changes in the system throughout a time period corresponding to a flow time downstream from a waste outfall. Values of ammonia, nitrite, and nitrate nitrogen; algae concentration, ortho-phosphate, poly phosphate, BOD reaction velocity constant "K", and ultimate BOD remaining, "La", were determined at times up to 7 days. These tests were conducted simultaneously on river water, river water with unchlorinated lagoon effluent, and river water with chlorinated lagoon effluent. Different ratios of lagoon effluent to river water were used. Results of a typical test series are shown in Figs. 20 through 29.

Disinfection of the chlorinated series was accomplished by introducing chlorine into a sample of lagoon effluent in a quantity sufficient to produce 0.5 mg/L residual after 15 minute contact. The chlorinated effluent was then introduced to the simulated stream, together with Willamette River water.

River water by itself had insufficient nutrients to support a significant algal population. While a sparse plankton population was present, additional growth did not take place. Introduction of unchlorinated effluent added both a significant algal population and needed nutrients. An increase in plankton population resulted in the unchlorinated test. While the same level of nutrients were added to the simulated stream in the chlorinated test channel, a gradual decline in algal population was noted (Fig. 21).

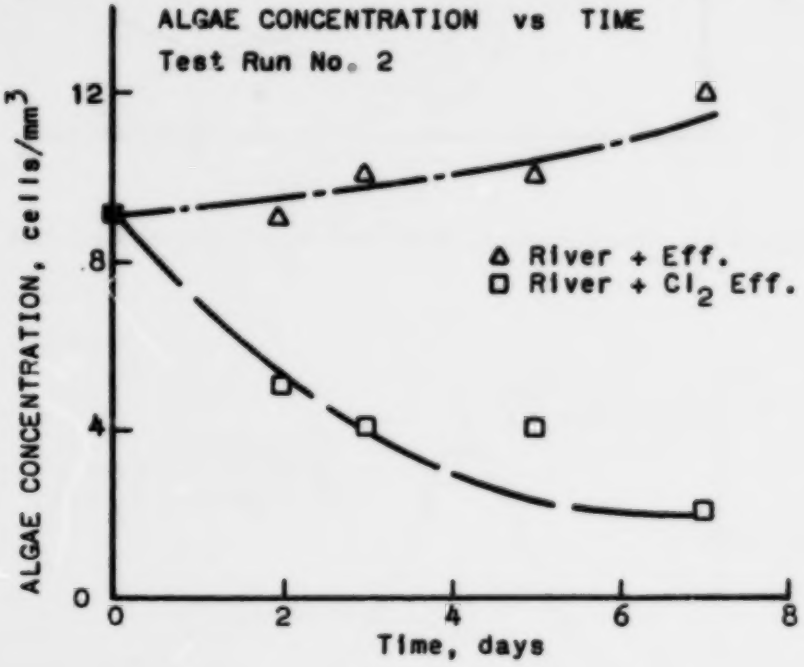

Figure 21. Variations in Algal Population

It is interesting to note that the decline was quite gradual, indicating possible long-term toxicity effects of the initial chlorination upon the algae. Their ability to reproduce in the stream was markedly diminished. Further study of this mechanism is planned.

BOD reaction velocity constant "K" determinations were made upon samples from the test channels at various time increments and are shown in Fig. 22. The ultimate first-stage BOD "La" value exhibited by water from the simulated streams was determined at the same time increments and is shown in Fig. 23.

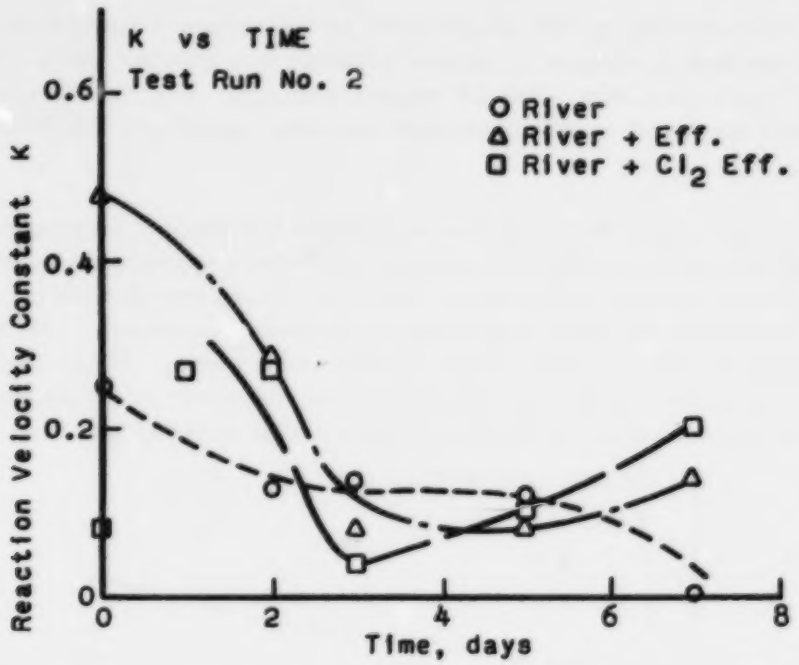

Figure 22. Variations in BOD Reaction Velocity Constant K

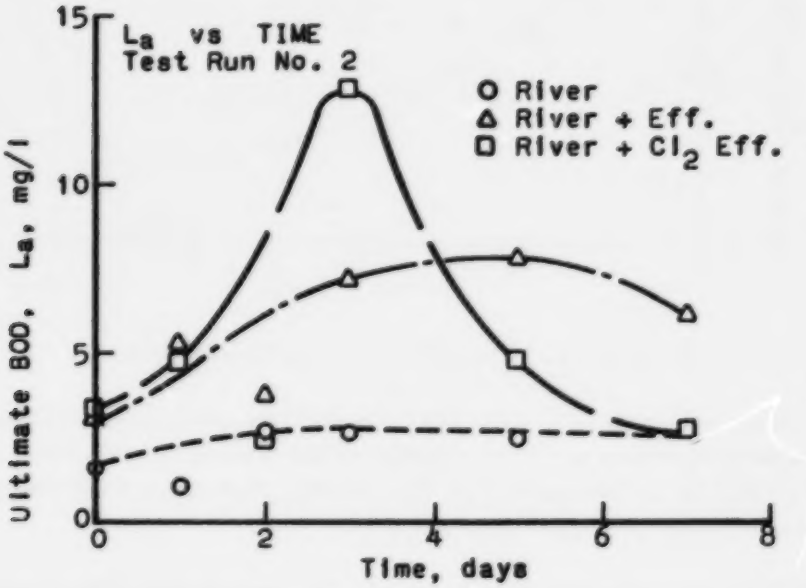

Figure 23. Ultimate First-Stage BOD Remaining at Times Indicated

It will be noted that the ultimate BOD of the river water was quite stable throughout the test, indicating a balance in the biological system of the river.

The ultimate BOD of the water in the channel that conta'ned river water plus unchlorinated lagoon effluent exhibited an increase during the test series. The ultimate BOD of the water in the channel containing chlorinated effluent demonstrated an initial increase reaching a maximum between the 2nd and 3rd day for all test series. A decrease in ultimate BOD followed which could be described by an exponential curve.

Since the value of L_a measured at various times represents the amount of decomposable organic matter present, "K" represents a rate of reaction, the first order equation of BOD satisfaction may be applied and a rate of utilization expressed as $\Delta L/\Delta t = KL_a$, yielding use rates existing at the time of sampling. Table 10 is a listing of such values for the test series illustrated.

Table 10. Utilization Rates vs Time

Time	(1) Chlorinated			(2) Unchlorinated			Ratio KL(1)/KL(2)
days	K	L	KL	K	L	KL	
0	-	3.4	-	0.48	3.0	1.44	-
1	0.32	4.8	1.53	0.41	4.2	1.74	0.88
2	0.2	8.4	1.68	0.28	6.0	1.68	1.00
3	0.04	12.8	0.10	0.12	7.2	0.86	0.12
4	0.08	7.8	0.62	0.08	7.8	0.62	1.00
5	0.10	5.0	0.50	0.08	8.0	0.64	0.78
6	0.15	3.0	0.45	0.10	7.5	0.75	0.60
7	0.20	2.6	0.52	0.14	6.0	0.84	0.62

Because of the large number of determinations necessary to construct these data, it has not been possible to complete a sufficient number of test series to justify specific conclusions. However, a few general observations may be made as follows:

1. Disinfection with chlorine results in destruction of the plankton population and contributes additional decomposable organic material to the receiving stream.

2. A period of 2 to 3 days was required in the simulated stream for the full effect of the increased load to materialize as measured by ultimate BOD. The reaction velocity constant is usually lowest at this time, resulting in a rate of utilization $\Delta L/\Delta t$ that is not materially higher than the initial rate. This lag may be partially attributed to time required for dead cells to become available as a bacterial food.

3. Biochemical oxygen demand (BOD) is not a reliable measurement of pollutional load for wastes of this nature unless a detailed and complete analysis is made to determine the portions of BOD due to bacterial respiration in the metabolism of organic wastes present, respiration of the plankton population present, and bacterial respiration in utilizing organic material contributed by dead plankton cells. Methods of doing this easily have not yet been devised. Values of the variation in "K" and L with time, in addition to others shown, must also be determined for evaluation of the meaning of BOD data.

Data on nitrogen and phosphate transformations are shown in Figs. 24 and 25. Figures 25 through 30 give typical BOD-time tests, and are found in the appendix.

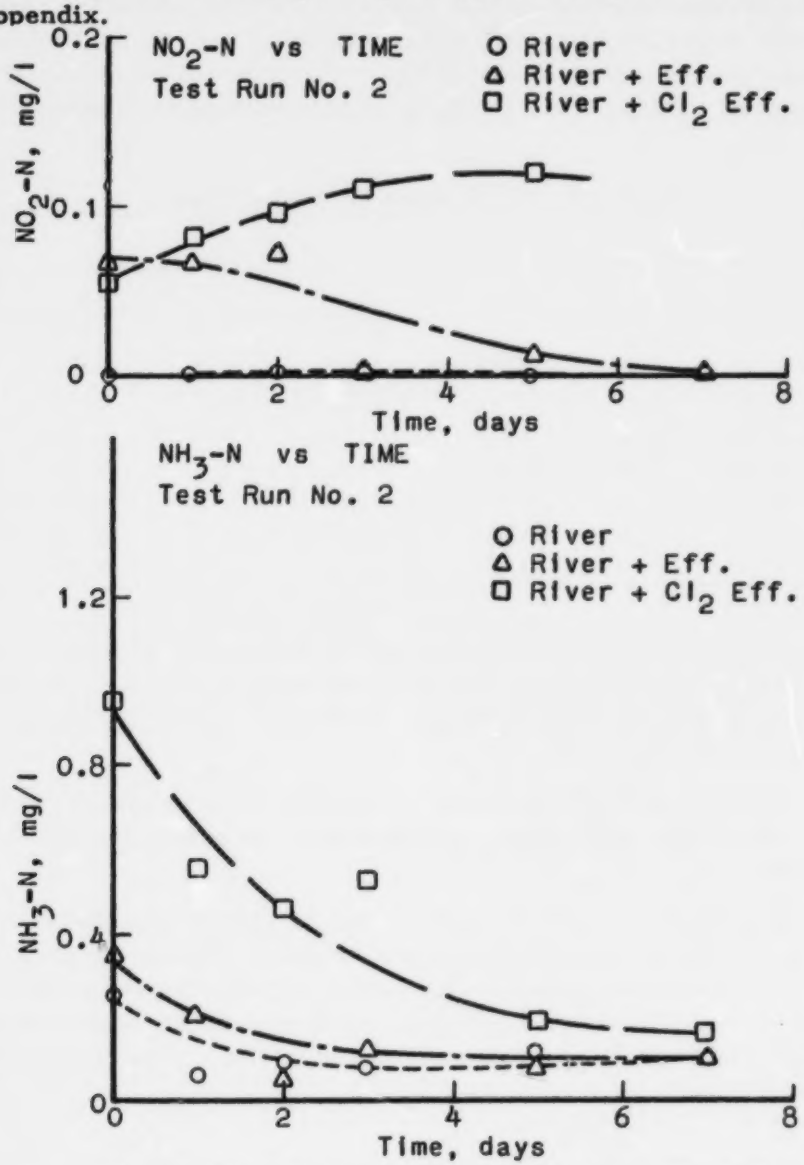

Figure 24. Ammonia-Nitrite Nitrogen Variations

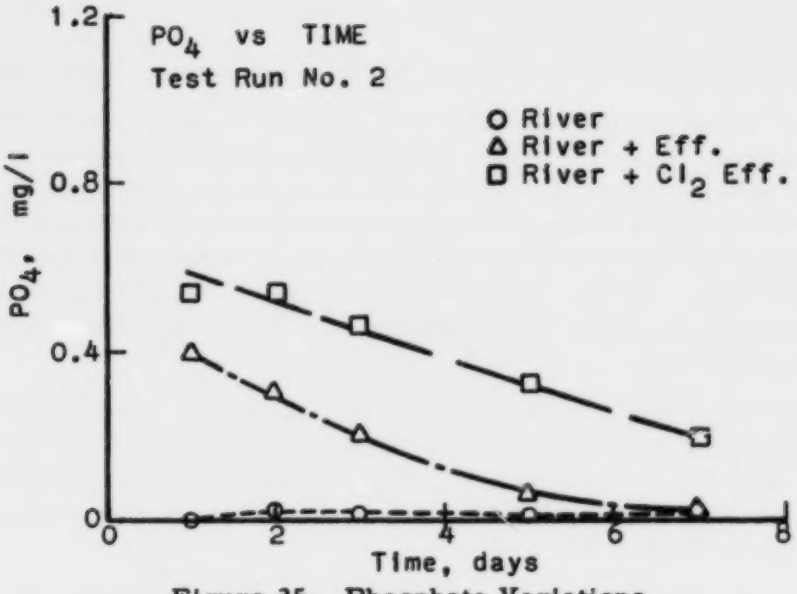

Figure 25. Phosphate Variations

CONCLUSIONS

Much of the work of this research is still in progress and findings are not sufficiently complete to draw specific conclusions on some of the problems involved in waste water lagoon criteria for maritime climates. Results of research to date in some areas of study are adequate to conclude the following:

1. Waste water oxidation lagoons may be used successfully as a treatment process in the maritime regions of the Pacific Northwest.

2. Present criteria of 20 lb of 5-day BOD per surface acre per day (i.e., population equivalent of 120 persons) as a design value for critical periods of early spring and late fall are entirely feasible. This value provides a factor of safety consistent with good engineering design. The magnitude of this factor of safety is not yet adequately determined, but is believed to be between 1.5 and 2.5.

3. Shock loadings four to six times in excess of the above value can be tolerated for short periods of time. The length of time and magnitude of such shock loading is the subject of continued research.

4. Allowable loadings may be increased during summer months of high solar energy (i.e., light intensity). Design should therefore be viewed in terms of the variation of loading throughout the year.

5. Efficiencies of BOD removal do not reflect a strong correlation with loading rate. The efficiency is strongly influenced by algae growth, wind, sludge blanket disturbance, and other factors that affect effluent

quality.

6. BOD reduction is not a reliable measure of lagoon performance.

7. A large reduction of sewage bacteria occurs in the lagoon treatment process. However, the concentration in the effluent of bacteria associated with human wastes is still significant and a potential health hazard exists. In view of these findings, lagoon effluent should be disinfected prior to discharge into a stream above a source of water supply or other "health critical" water uses. (Note: Research on the public health significance of bacteria present is currently being done by the U.S. Public Health Service to evaluate this problem.)

8. Significant reaeration of a lagoon occurs during periods of dissolved oxygen deficit by transfer of oxygen to the lagoon from the atmosphere. (See section on reaeration.) This mechanism provides a factor of safety against destruction of the algal populations that are the major source of oxygen by toxicity or other causes.

9. Highly colored domestic or industrial wastes interfere with light penetration, thereby reducing algal activity and severely limiting the lagoon's ability to accommodate high loading rates.

10. To provide maximum flexibility, a lagoon installation should consist of two or more cells designed to operate in series or parallel and provide for reversing the order of the cells.

11. Total disposal of the effluent during summer months by utilizing evaporation plus storage is entirely feasible for the climatological characteristics encountered in the Pacific Northwest. Design of such a system must be predicated on local weather data.

12. Definite provisions for maintenance of lagoon dikes, control of marginal grass, and other operational problems must be provided to avoid unsightly and nuisance conditions.

FUTURE RESEARCH PLANS

In order to obtain maximum objectivity, general research goals have been established for this project. Since the problem of using oxidation lagoons in maritime areas is immediately pressing, it is not reasonable to wait resolution of all basic questions before adopting application criteria. Therefore, the basic philosophy during this study has been to proceed on a twofold approach of placing major emphasis on application problems while investigating the more basic problems as a long-term goal.

Many of the research goals of the investigators are not funded under the present grant. They are considered necessary, however, and have been included here for purposes of enumeration. They are as follows:

1. Determination of loading criteria. Determining the upper dependable limit of loading that will permit aerobic oxidation will remain a primary objective of this project. This value will be variable, depending upon climatological conditions, waste water quality, solar radiation, volumetric loading, and other parameters. Studies to determine these relationships on the experimental lagoon and on existing municipal facilities will be continued in order to access factors of safety and guide establishment of critieria.

2. Bacteriological quality of lagoon effluent. The bacteriological quality of a lagoon effluent will vary with time, hydraulic characteristics, and environmental factors. Since this quality reflects a potential health hazard, studies will be made of the bacteriological quality of the experimental lagoon and at other available lagoon installations throughout the state as a continuing part of this work.

3. Receiving stream effects. Research on the effects that both chlorinated and unchlorinated lagoon effluent has upon the receiving stream will be continued in this project.

4. Reaeration mechanics. Studies on reaeration mechanisms, both from surface and plankton sources, will be continued. Mixing as a function of depth, wind velocity, and boundary conditions will be included as possible. Extending this work to other available lagoon installations is planned. Necessary equipment has been requested to permit such a study.

5. Water balance. Since preventing a discharge during the dry summer months would resolve the problem of disinfection and possible downstream pollution, studies will be continued on evaporation potential and the problems of controlled effluent discharge by storage-evaporation mechanisms.

6. Effluent quality measurement. Because the major portion of organic material in the lagoon effluent is in the form of living cells, more work on suitable tests of effluent quality must be done. Such a measure is badly needed to predict effluent effects on receiving streams.

7. Soil sealing. Preventing contamination of ground water and excessive losses of water that may result in stranding of sludge deposits is a problem, particularly with lagoons located in porous soils. Studies of this nature are being planned.

8. Sludge accumulation. Much of the work of stabilization in an oxidation lagoon proceeds in the lagoon benthos. Studies of sludge accumulation, respiration rate, and oxidation mechanisms will continue as a long-term goal of this project. These studies will largely be conducted on existing field lagoon facilities.

9. Industrial waste application. Adaptation of oxidation lagoons to highly colored industrial wastes will be a major long-term objective of this program. Evaluation of light extinction coefficients, oxygen production, and nutritional requirements is planned as a future phase of this study.

10. Coastal area application. Lagoons offer an ideal waste disposal solution to coastal resort areas with a large temporary population. It may be necessary to supplement lagoon water levels with salt water in such areas due to low volumetric loading in times of low tourist use. The effect of varying salinity and shock loading is considered a necessary study area.

11. Mechanism of odor production. Control of odor nuisance is extremely important to satisfactory operation. Conditions in the sludge blanket, rate of release of odor producing gases, mixing currents, and physical-chemical conditions within the liquid phase are important considerations in this problem. Work on this problem is also planned as a future part of this project.

APPENDIX

Experimental Data

Data Legend

Color

Code No.	Description
1	Green
2	Greenish gray
3	Gray-green
4	Gray

Odor

No.	Description
Blank	None
1	Very slight
2	Slight
3	Medium
4	Objectionable

Aquatic Forms

A	Posillium	H	Holophra
B	Chlorella	J	Coelastrum
C	Chlorogonium	M	Micratinium
D	Phycotonis	P	Pyrobotrys
E	Euglena	S	Scenedesmus
F	Filamentous green	R	Rotifera
G	Uncoded green		

Units Used in Reporting

Item	Description of units
Flow	Thousands of gallons
Loading BOD & suspended solids	Average of preceding 10-day period
Effluent quality	Measurements of quality at 2:00 PM daily
Physical appearance	Qualitative, based on observer opinion
Precipitation	Inches daily & cumulative total
Precipitation-evaporation	Weekly total (pond reading)
Evaporation	Weekly calculated
Transmittance	Percent at 10 mm light path, 650 micron wave length
Plankton data	
Cell numbers	Per cubic millimeter
Cell volume	Mls per 100 mls of water
Specie	See code

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Units Used in Reporting (continued)

Item	Description of units
Bacteriological	Coliform organisms per milliliter (Millipore filter method)
Cl_2 requirement	Mg/L required to obtain 0.5 mg/L residual at end of 30-minute contact

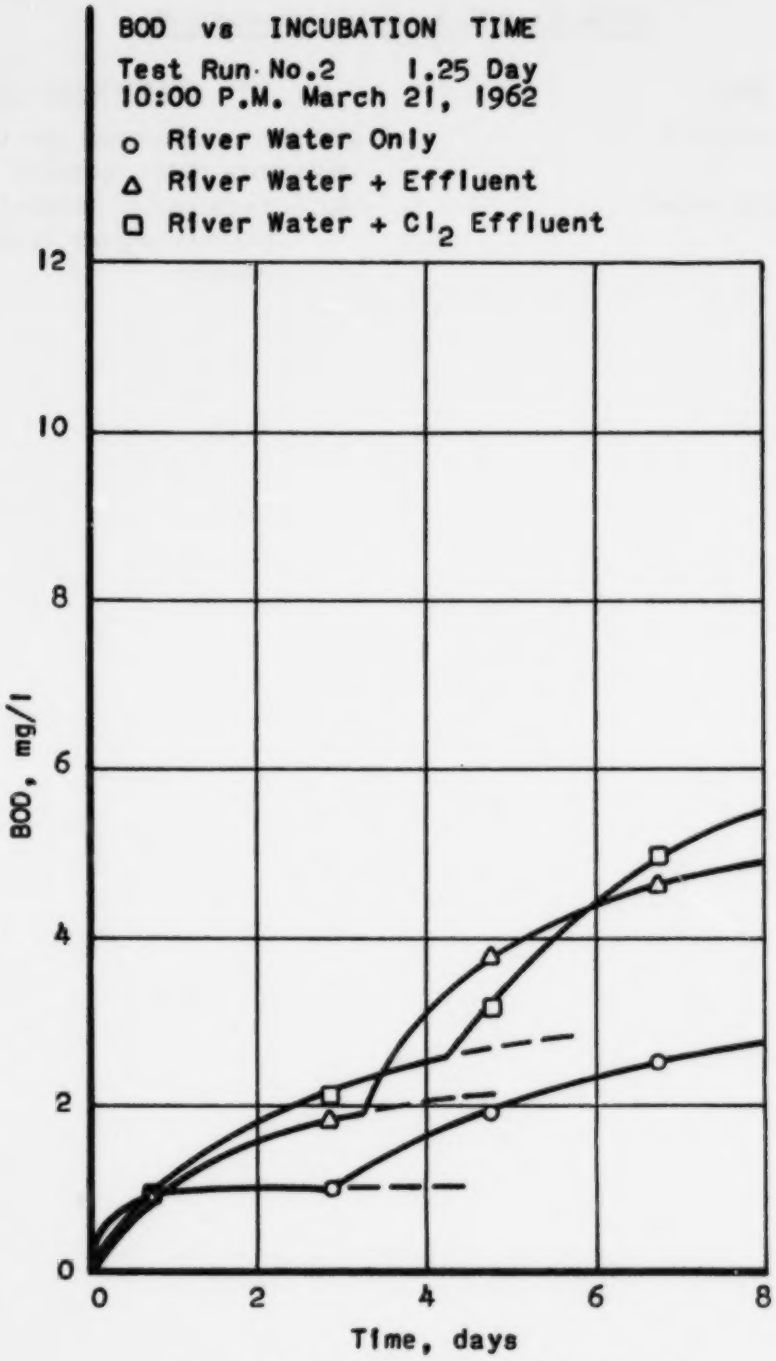

Figure 26. BOD - Time Relationship
Sample Collected at Time Indicated

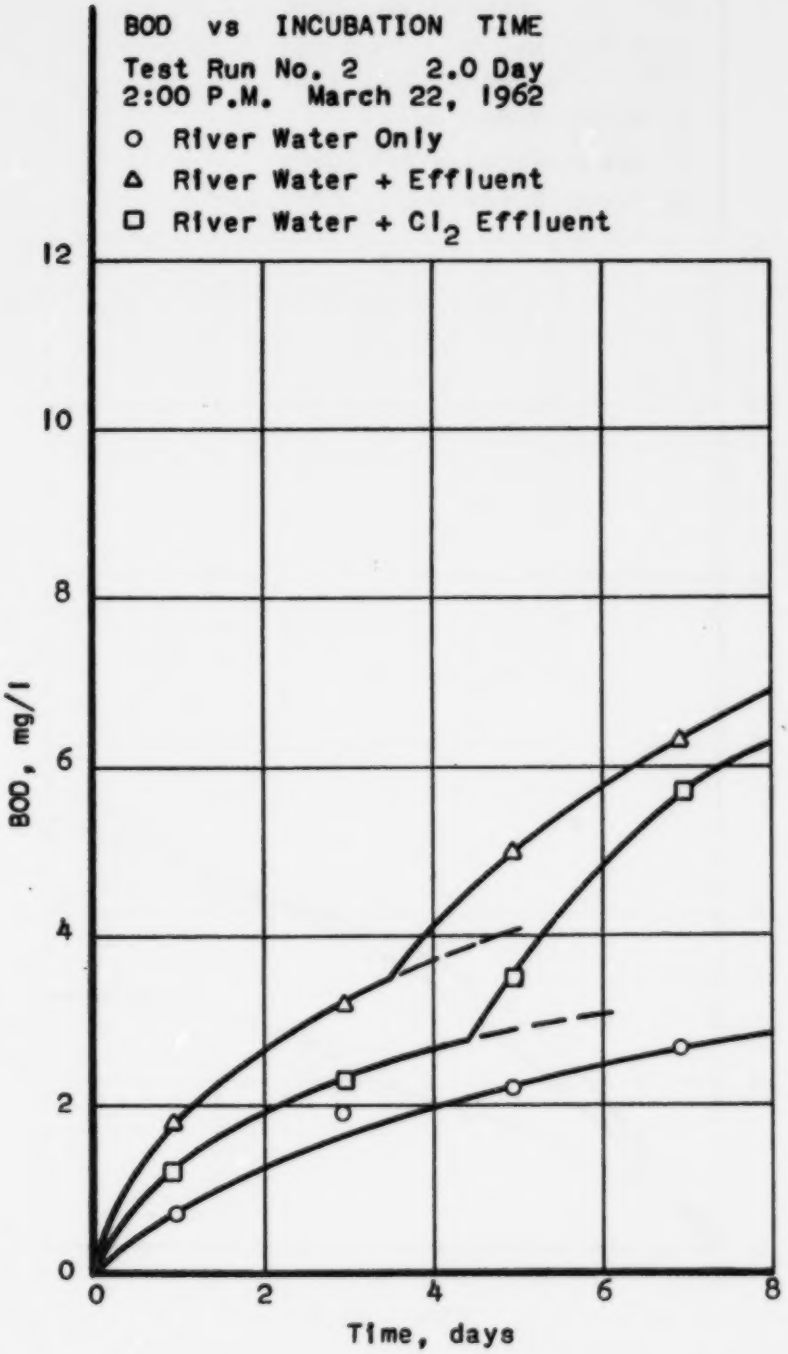

Figure 27. BOD - Time Relationship
Sample Collected at Time Indicated

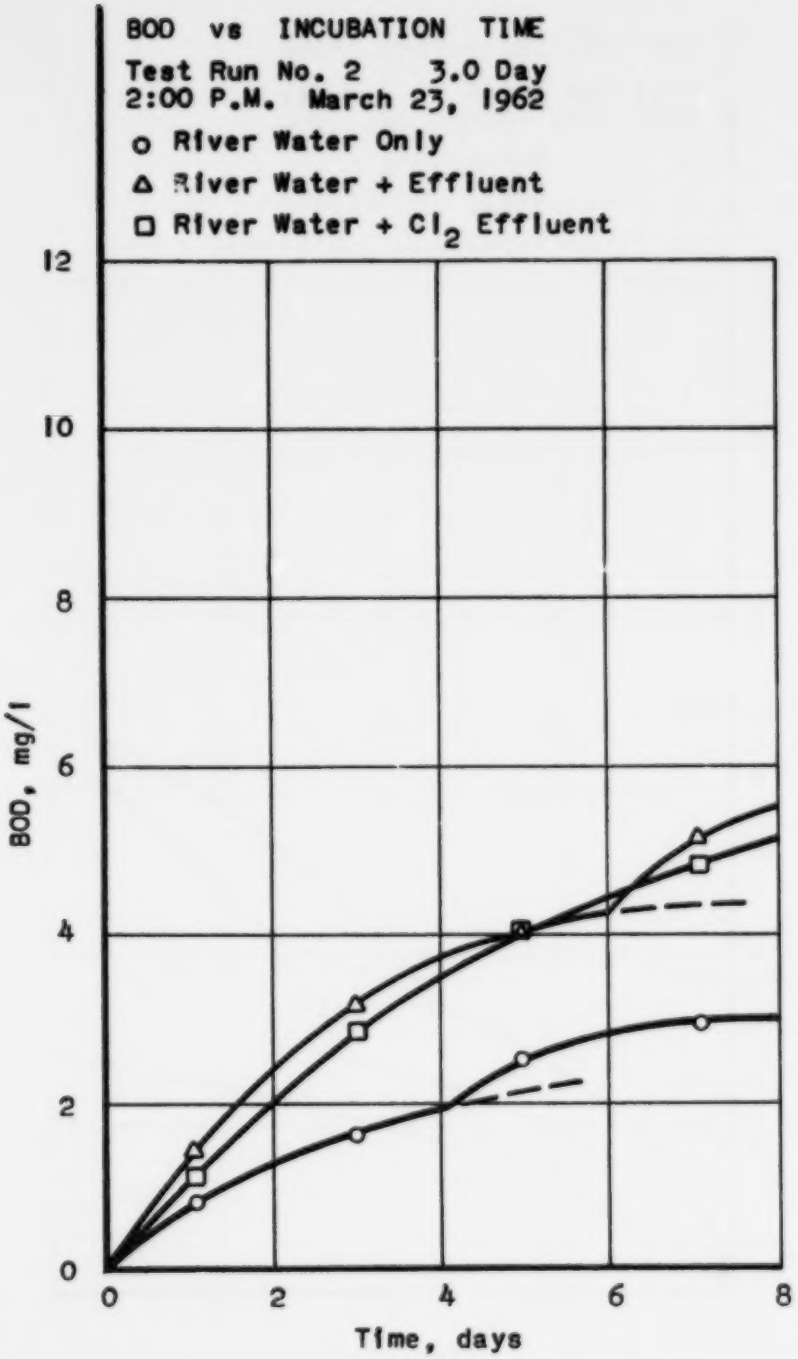

Figure 28. BOD - Time Relationship
Sample Collected at Time Indicated

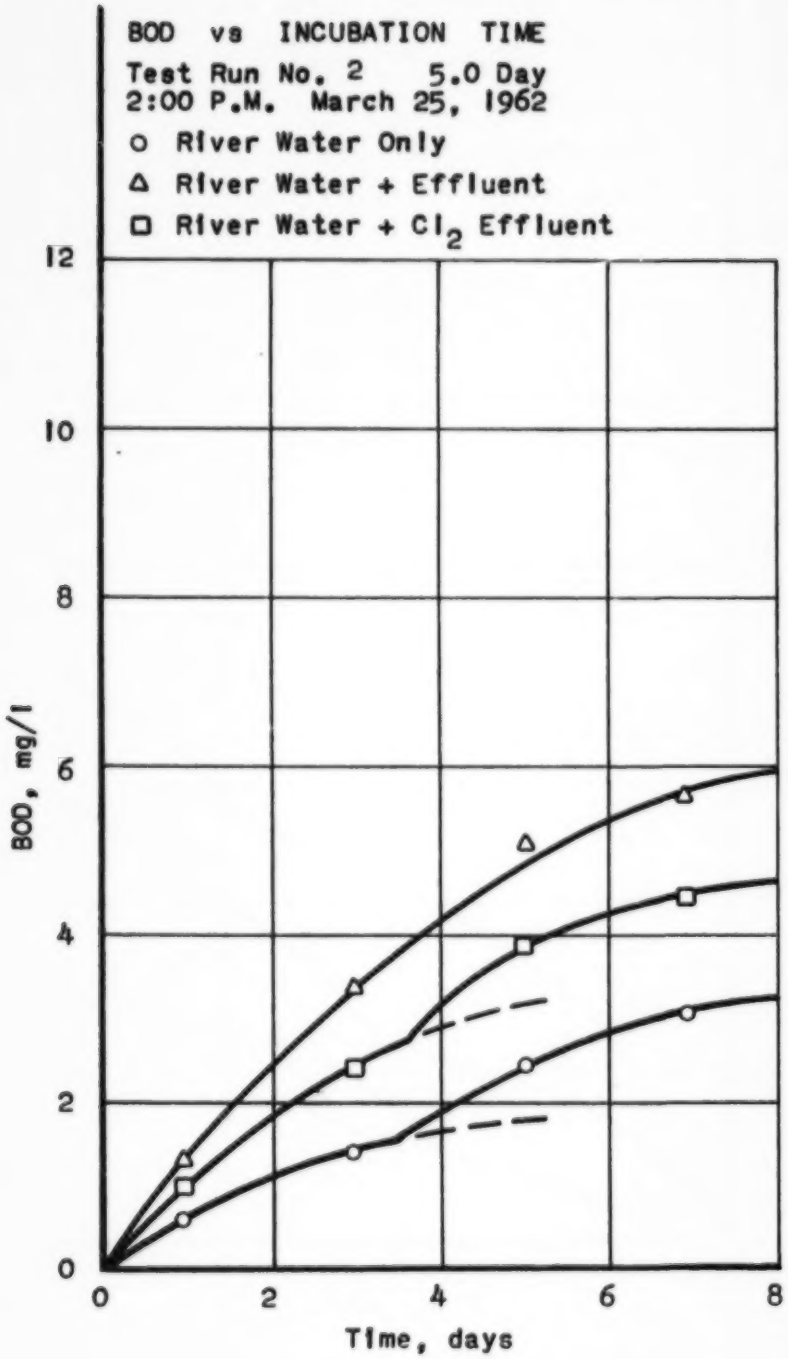

Figure 29. BOD - Time Relationship
Sample Collected at Time Indicated

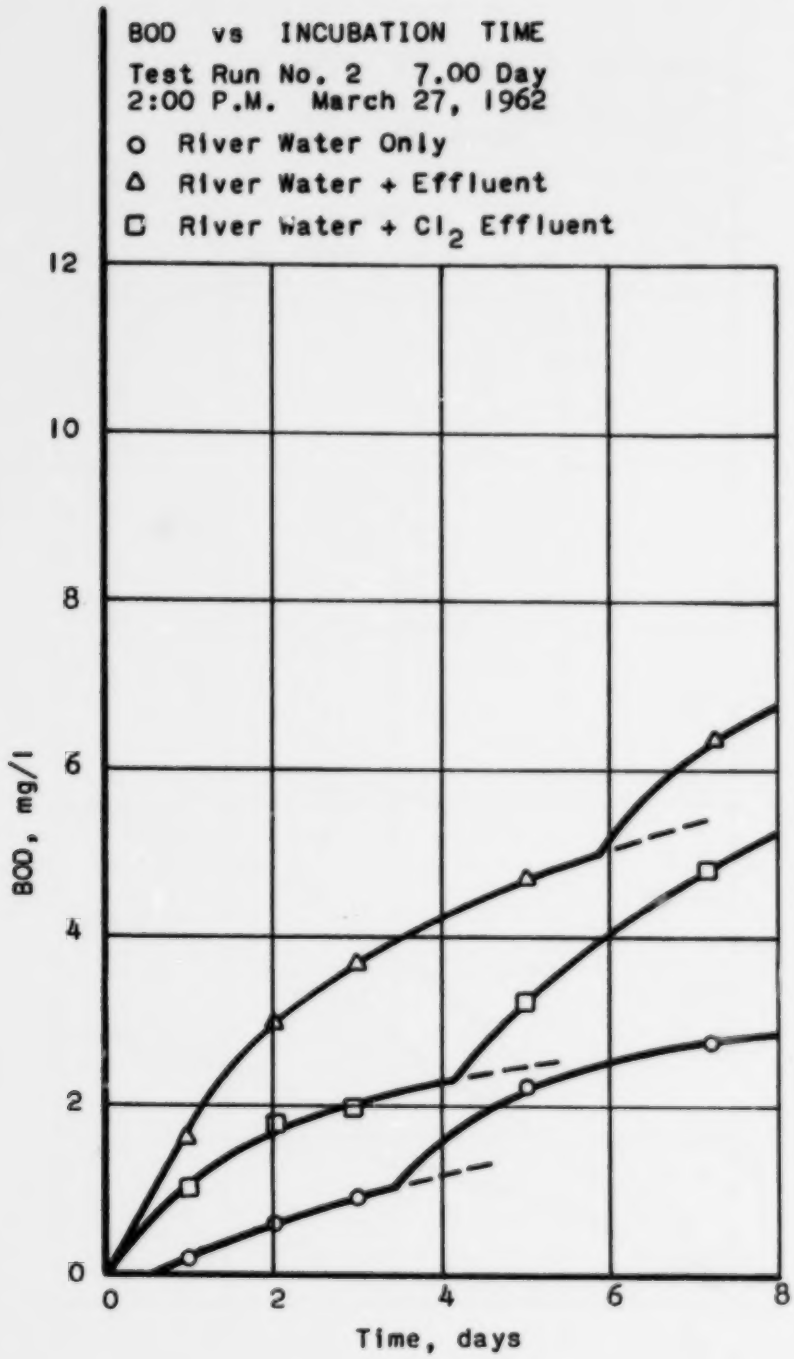

Figure 30. BOD - Time Relationship
Sample Collected at Time Indicated

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
April	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1													
2													
3													
4	85.68	140	412	95.6	47.8			20	17	20.4	19.8	7.0	7.3
5	85.68	226	384	95.6	47.8			24	23	21.1	19.1	9.6	9.0
6	85.68	195	268	95.6	47.8			18	11	26.7	32.9	9.7	9.5
7	85.68	165	256	95.6	47.8			27	23	21.8	19.5	8.6	8.6
8	85.68		384	95.6	47.8					10.1	13.6	8.3	7.9
9	85.68	310	616	95.6	47.8			32	26	17.8	18.6		
10	85.68			95.6	47.8								
11	85.68	144	76	95.6	47.8			32	16	14.4	13.4	8.7	9.2
12	85.68	288	436	95.6	47.8			29	19	13	12	8.2	8.2
13	85.68	264	736	95.6	47.8	199.2	99.6	72	22	13.5	12.1	9.3	8.8
14	85.68	140	464	95.6	47.8	201.0	100.7	26	28	12.8	13.5	8.1	7.9
15	85.68	120	184	91.0	45.5	192.8	96.4	22	22	13.6	13.1	8.8	8.7
16	85.68	70	60	85.8	42.9	192.6	96.3	16	19	30.4	38.0	9.4	10.2
17	85.68	270	344	90.4	45.2	194.6	97.3	36	35	13.6	14.0	8.8	8.2
18	85.68	304	840	93.2	46.6	214.2	107.1	70	62	12.7	14.3	8.1	8.0
19	85.68			90.4	45.2	212.4	106.2						
20	85.68	185	300	88.2	44.1	201.4	100.7	47	46	13.4	14.2	9.3	9.0
21	85.68	160		89.0	44.5	194.9	97.2	48	51	15.9	18.1	8.1	9.0
22	85.68	185	362	84.6	42.3	191.0	95.5	20	18	24.2	24.8	9.8	9.9
23	85.68	192	488	81.4	40.7	180.4	90.2	30	28	21.7	25.3	8.2	9.8
24	85.68			85.4	42.7	176.8	88.4						
25	85.68	210	410	88.2	44.1	186.6	93.3	35	36	13.8	12.6	9.3	8.6
26	85.68	158	340	91.8	45.9	190.0	95.0	33	29	29.6	30.3	9.6	9.5
27	85.68	150	242	86.4	43.2	185.6	92.8	31	35	11.6	5.5	8.8	9.0
28	85.68	258	438	84.4	42.2	168.2	84.1	44	26	21.8	21.8	9.4	9.3
29	85.68	284	452	86.2	43.1	163.0	81.5	25	18	32.4	30.6	10.4	10.8
30	85.68	330	578	92.6	46.3	175.2	87.6	43	53	22.7	20.5	9.6	10.0

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Date	Temperature			Solar	Physical Appearance				Precip.	Evap.	P-E	Transmittancy	
1960		°F		Data	Odor		Color		P	E		inf.	effluent
Apr	air	W	E	$\frac{gm\ cal}{cm^2}$	W	E	W	E	in.	in.	in.	W	E
1				205.5					0.13				
2				436.1					0.03				
3				482.7					0				
4		68	73	518.9					0				
5		67	67	424.9					0				
6		73	72	427.3					0				
7	75	69	66	450.7					0.11				
8		62	62	326.8					0				
9		64	62	411.8					0.03				
10				512.7					T				
11	46	60	60	409.3					0.31				
12	54	58	57	231.7					0.09				
13		58	58	--					0.23				
14	60	56	56	--					0.36				
15		55	55	--					0.46				
16		64	68	551.1					0.03 (1.78)	1.07	$+0.708^{P}$		
17		53	54	211.3					T				
18		54	54	154.1					0.12				
19				224.6					0.31				
20		55	55	405.8					0.50				
21		54	55	323.5					0.09				
22		60	61	551.1					0.30				
23		58	58	454.4					T (1.32)	0.72	$+0.60^{P}$		
24				249.3					T				
25	53	55	54	297.4					0.01				
26	65	67	66	555.2					0.09				
27		58	57	157.8					T				
28	60	65	64	626.7					0.07				
29		70	70	513.7					T				
30		66	66	543.8					0 (0.17)	0.63	-0.456^{E}		

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
May	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68			102	50.9	189.8	94.9	32	29	13.1	9.0	9.5	9.1
2	85.68	415	774	112	55.9	207.4	103.9						
3	85.68	201		112	56.1	205.4	102.7	30	24	10.5	16.6	8.8	9.3
4	85.68	282	538	116	57.8	212.2	106.1	26	23	26.1	23.0	9.5	9.9
5	85.68	252	532	117	58.7	217.6	108.8	38	28	22.4	22.8	9.8	9.6
6	85.68	186	202	118	59.3	210.6	105.8	35	29	8.7	2.7	9.4	8.9
7	85.68	210	318	121	60.7	214.8	107.4	35	37	8.0	3.0	8.2	9.0
8	85.68			122	60.9	214.0	107.0						
9	85.68	326	530	124	61.8	217.4	108.7	33	32	24.8	27.5	9.6	9.8
10	85.68	279	326	121	60.7	206.4	103.2	33	36	25.0	19.6	9.6	9.7
11	85.68	244	272	116	57.9	188.8	94.4	34	26	33.4	23.1	10.6	10.4
12	85.68	212	702	107	53.5	185.8	92.9	33	43	9.0	5.9	9.0	8.5
13	85.68	156	528	105	52.5	190.2	95.1	36	31	9.1	8.7	9.1	9.0
14	85.68	192	222	101	50.6	176.4	88.2	31	26	29.8	32.2	9.6	9.7
15	85.68			98	48.8	162.6	81.3						
16	85.68			96	48.0	162.8	81.4						
17	85.68	126	194	92	46.1	157.4	78.7		37	13.3	12.9	8.8	9.0
18	85.68	102	194	85	42.5	147.4	73.7	36	34	14.0	15.7	9.1	9.3
19	85.68	150	568	77	38.6	149.2	74.6	35	36	17.6	15.1	9.2	8.8
20	85.68	132	178	71	35.4	142.8	71.4	32	41	10.8	8.0	8.7	8.4
21	85.68	84	214	64	31.9	140.2	70.1	40	42	15.7	12.0	8.6	8.5
22	85.68	81		60	29.8	124.2	62.1						
23	85.68	77		59	29.5	121.2	60.6						
24	85.68	168	532	58	29.1	134.8	67.4	52	60	10	6	8.5	8.3
25	85.68	108	164	55	27.6	132.6	66.3	66	54	0.2	0.2	7.9	7.9
26	85.68			54	26.9	129.8	64.9						
27	85.68			54	26.9	126.6	63.3						
28	85.68	126	90	55	27.4	122.2	61.1	46	60	12.6	17.7	9.2	9.2
29	85.68	204	418	57	28.6	115.6	57.8	36	38	15.8	31.1	9.8	10.0
30	85.68			59	29.4	120.6	60.3						
31	85.68	142	168	61	30.7	118.6	59.3	40	36	35.6	28.2	10.3	10.6

Date	Temperature			Solar	Physical Appearance				Precip.	Evap.	P-E	Transmittancy	
1960	°F			Data	Odor		Color		P	E		infl.	effluent
May	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.	W	E
1				418.5					0.01				
2	57	64	61	554.5					T				
3	51	60	60	198.2					0.01				
4	55	66	66	338.8					0.32				
5	69	69	72	602.1					0.03				
6		62	60	125.4					T				
7	60	60	60	413.9					0.35 (0.72)	1.02	E -0.30		
8				697.5					T				
9	75	75	72	590.1					0				
10	65	71	70	432.2					0				
11	65	72	79	459.4					0.02				
12	57	64	63	338.5					0.16				
13	61	62	62	416.6					0.64 (0.82)	0.92	E -0.096		
14	61	67	68	403.1					0.03				
15				416.5					T				
16				461.7					0.14				
17	55	60	59	413.6					0.21				
18	60	61	61	547.8					0.29				
19	61	61	61	204.3					0.01				
20	51	60	59	302.9					0.32				
21	55	59	60	61.4					0.13 (1.13)	0.90	P +0.228		
22				460.7					0.17				
23				484.4					0.14				
24	59	61	61	422.1					0.19				
25	55	60	59	195.2					0.22				
26				406.0					0.52				
27				594.5					0.01				
28	56	58	58	643.1					0 (1.25)	0.75	P +0.50		
29	77	75	78	740.6					0				
30				598.2					0				
31	73	78	75	644.5					T				

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
June	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68	240		66	33.4	120.6	60.3	18	17	33.4	23.1	11.0	10.4
2	85.68	246	596	71	35.6	126.6	63.3	13	24	39.1	19.3	10.6	10.0
3	85.68	252	436	75	37.4	122.4	61.2	17	19	35.3	18.4	10.6	9.8
4	85.68	246	312	81	40.4	128.8	64.4	38	31	27.0	33.6	10.2	10.4
5	85.68			87	43.8	138.0	69.0						
6	85.68			95	47.6	150.0	75.0						
7	85.68	321		104	51.9	165.0	82.5	51	51	12.3	17.5	9.0	8.9
8	85.68	262	472	106	53.2	167.4	83.7	28	63	17.7	27.4	9.2	9.6
9	85.68	364	728	115	57.4	186	93.2	44	32	33.7	36.7	10.4	10.8
10	85.68	360	762	124	62.1	212.4	106.2	60	37	10.4	7.6	9.2	8.9
11	85.68			128	64.1	224.8	112.4	53	48	24.1	25.7	10.0	9.6
12	85.68			131	65.4	223.6	111.8						
13	85.68	276	474	132	65.9	235.2	112.6	52	60	30.3	27.7	10.2	10.7
14	85.68	360	734	137	68.4	243.6	121.8	42	35	0.2	5.0	8.6	10.6
15	85.68	342	546	140	69.9	262.0	131.0	34	46	1.3	2.5	8.4	8.5
16	85.68	258	456	140	70.0	264.6	132.3	32	34	11.4	8.7	8.7	8.5
17	85.68	390	644	143	71.5	273.6	136.8	43	44	27	34	9.7	9.5
18	85.68	273	460	143	71.7	273.0	136.5	38	32	12.9	11.0	8.6	8.5
19	85.68			138	69.1	261.0	130.7						
20	85.68	217		132	66.0	248.6	124.3	23	23	33.3	39.6	9.8	10.0
21	85.68	284	474	130	65	240.2	120.1	31	28	22.4	22.3	9.4	9.3
22	85.68	160	302	134	61.9	228.6	114.3	26	20	23.9	32.8	9.9	9.9
23	85.68		434	129	59.7	226.8	113.4			25.6	23.5	10.0	9.9
24	85.68	189	334	112	56	209.4	104.7	48	29	22.1	20.7	10.5	10.2
25	85.68		242	106	53.3	186.2	93.1			24.4	25.5	10.2	10.2
26	85.68			104	51.9	183.4	91.7						
27	85.68			98	49.1	178.8	89.4	39	51	27.1	23.4	10.7	10.5
28	85.68	292	432	99	49.5	177.6	88.8	59	42	17.5	21.0	9.5	9.8
29	85.68	217		97	48.4	174.4	87.2	32	48	12.6	21.5	9.5	9.8
30	85.68	175	346	95	47.5	169.0	84.5	67	29	1.6	9.2	8.0	10.0

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
June	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1	79	86	83	747.9					0					
2	82	84	83	759.1					0					
3	82	83	83	754.6					0					
4	77	82	81	771.0					0 (0)	1.35	E -1.35			
5				728.2					0					
6				749.6					0					
7	66	73	71	786.4			2	1	0					
8	72	76	76	781.1			2	1	0					
9	77	81	81	754.3			2	1	0					
10	72	74	74	798.5			1	1	0					
11	76	78	78	784.4			1	1	0 (0)	1.77	E -1.77			
12				755.3					0					
13	82	84	84	678.8			1	1	0					
14	69	70	71	183.7			1	1	0					
15	73	69	69	428.3			1	1	0.22					
16	74	70	71	606.9			1	1	0					
17	64	73	73	--			1	1	0					
18		71	68	674.6			1	1	0 (0.22)	1.28	E -1.06			
19				513.4					0					
20	70	73	75	548.1			1	1	T					
21		71	71	785.5			1	1	0					
22	73	78	78	768.5			1	1	(0) 0	0.64	E -0.64			
23	82	84	85	759.1			1	1	0					
24	72	77	76	695.0			1	1	0					
25	68	75	75	803.6			1	1	0 (0)	0.77	E -0.77			
26				746.1					0					
27	75	83	82	777.8			1	1	0				88	87
28	79	82	81	752.5			1	1	0				86	91
29	73	82	82	536.8			2	1	0			80	87	90
30	72	73	72	438.9			2	1	0			86	73	86

Date	Flow	Waste		10 day ave. load					Effluent Quality				
1960	1000	analysis		BOD /acre /day		SS /acre/day		BOD		DO at 2 pm		pH at 2 pm	
July	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	85.68	272	222	94	47.2	164	82.2	43	46	7.6	23.8	8.4	9.8
2	85.68	280	346	100	49.8	168	84.2	36	37	11.5	19.0	8.7	10.1
3	85.68			106	52.8	172	86.0						
4	82.10	343	638	112	56.2	185	92.6	29	42	15.9	22.7	8.6	10.2
5	82.10	312	784	116	58.3	209	104	32	43	17.6	23.2	9.3	10.5
6	84.00		324	119	59.6	205	103			25.7	19.6	9.6	10.1
7	84.00	287	440	120	60	201	100.7	32	62	21.6	22.0		
8	84.00	280	444	120	59.9	202	101	46	46	13.3	21.5	9.2	10.1
9	84.00	350	690	126	63.3	215	107.5	95	79	11.1	2.0	9.2	9.4
10	84.00			134	67.1	228	114.2						
11	84.00	350	610	138	68.8	239	119.5	41		30.9	13.0	9.2	9.0
12	84.00	290	348	138	69	245	122.3	66	68	13.9	20.5	8.8	9.1
13	82.10	308	764	138	68.8	255	127.7	84	38	4.8	0	9.1	8.9
14	82.10	260	460	134	66.8	247	123.6	52	41	14.6	11.1	9.2	9.4
15	82.10	232	578	130	64.9	240	118.9	81	23	10.9	7.2	8.3	8.4
16	82.10	245	348	127	64	238	119	20	6	19.2	6.2	8.7	7.7
17	82.10			125	62.5	236	117.6						
18	82.10	231	392	123	61.3	232	116	34	20	22.7	20.0	9.0	8.2
19	82.10	216	498	117	58.3	224	111.8	22	47	25.0	17.0	9.1	8.2
20	82.10	270	456	113	56.5	215	107.3	23	16	20.4	17.5	9.1	9.1
21	80.00	231	402	107	53.7	205	102	25	14	18.4	14.7	9.1	9.3
22	80.00			106	52.8	203	101	30	41				
23	80.00	287	620	104	52.2	196	98	35	16	16.2	15.5	9.1	9.0
24	80.00			102	51.2	197	98.5						
25	80.00	140	360	98	49.2	188	73.7	51	53	18.3	23.2	9.4	9.6
26	78.10	252	456	98	49.2	191	95.8	47		11.5	10.5	8.4	9.2
27	78.10	226	338	99	49.4	189	94.5	34	42	28.5	38.0	10.4	10.7
28	78.10	259	186	99	49.7	180	90	38	42	22.8	26.1	10.1	10.6
29	78.10	190		98	48.9	171	85.7	37	53	16.6	22.1	9.7	10.6
30	78.10	196	436	94	47.1	169	84.8	50	31	2.7	2.9	8.6	8.9
31	78.10			94	47.0								

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
July	Air	W	E	$\frac{gmcal}{cm^2}$	W	E	W	E	in.	in.	in.		W	E
1	68	74	74	627.4			1	1	0					
2	73	75	75	779.2			1	1	0 (0)	1.78	E -1.78			
3				770.4					0					
4	80	78	78	779.5			1	1	0					
5	89	82	81	744.7			1	1	0					
6	97	92	94	760.5			2	1	0					
7	85	83	84	717.6			2	1	0					
8	77	78	78	788.2			2	1	0					
9	76	77	74	--			3	1	0 (0)	-1.96	E -1.96			
10							3	1	0					
11	78	82	77	--			3	1	0					
12	82	75	81	693.9			3	1	0			90	86	88
13				550.0			4	1	0					
14	78	80	79	743.7			4	1	0					
15	88			744.6			3	3	0					
16	93	85	85	732.4			2	*	0 (0)	1.37	E -1.37			
17				740.0					0					
18	87	87	88	696.6			1	1	0					
19	83	84	84	738.3			2	4	0					
20	79	79	78	755.6			2	3	0					
21	81	79	78	734.4			2	2	0					
22				738.3					0					
23	75	75	75	743.2			1	1	0 (0)	2.06	E -2.06			
24				688.3					0					
25	85	80	78	446.2			1	1	0					
26	93	83	73	567.9			3	1	T					
27	92	88	88	652.8			2	1	0					
28	93	87	87	704.7			2	1	0					
29	87	84	84	573.1					0					
30	74	74	74	609.1			2	1	0 (0)					
									0	1.77	E -1.77			

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
Aug	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	78.10	273		94	47.1	173.2	86.6	44	26	5.8	6.9	8.4	8.3
2	71.40	256	586	92	45.8	175.4	87.7	48	50	12.2	10.1	8.9	9.2
3	78.10	231	564	92	46.0	172.4	86.2	38	52	15.1	12.5	9.4	9.9
4	80.00			94	47.1	166.2	83.1	55	65			9.1	9.5
5	80.00	154	134	90	45.1	156.8	78.4	52	68	24.3	20.3		
6	80.00	231	212	89	44.5	146.8	73.4	35	54	16.9	13.2	9.5	9.6
7	80.00			86	42.8	145.8	74.9						
8	80.00	190	554	82	41.3	165.8	82.9	54	46	11.2	27.2	9.5	10.5
9	72.00	248	672	84	41.9	181.8	90.9	50	45	10.0	9.5	9.3	9.6
10	72.00	140	352	80	40.2	179.2	89.6	37	36	11.0	17.5	9.2	9.9
11	72.00	350	974	84	42.2	200.2	100.1	49	40	21.0	19.4	9.7	9.9
12	72.00	273	600	87	43.3	202.2	101.1	49	47	18.6	14.3	9.7	9.9
13	72.00		316	90	45.1	192.8	96.4			14.1	12.1	9.2	9.4
14	72.00			96	48.2	193.0	96.5						
15	84.00	360	718	106	52.8	203.0	101.5	48	39	12.6	10.6	9.2	9.4
16	84.00	262		107	53.6	210.6	105.3	70	60	28.4	32.1	10.0	10.7
17	84.00	420		118	59.2	212.2	106.1	57	42	17.8	16.8	9.5	9.7
18	84.00			131	65.5	207.4	103.7						
19	85.68	370	480	138	68.9	199.0	99.5	70	39	21.3	21.7	9.9	10.2
20	87.50	320	376	146	73.2	201.2	100.6	48	36	17.6	19.5	9.5	10.0
21	87.50			143	71.5	189.4	94.7						
22	87.50	190	940	140	70.0	206.4	103.2	57	39	3.3	8.9	8.1	9.0
23	87.50			137	68.4	225.2	112.6						
24	72.58	290	576	134	66.8	232.6	116.3	32	28	13.8	3.4	8.5	8.3
25	65.65			128	63.9	238.2	119.1						
26	65.65	250	608	125	62.7	242.2	121.1	51	57	15.1	13.9		
27	65.65	480	572	124	61.8	244.0	122.0	132.2	67	14.0	13.8		
28	65.65			123	61.7	246.0	123.0						
29	65.65	520	646	125	62.5	247.8	123.9	61	55	14.1	8.4	7.6	9.4
30	65.65			125	62.4	248	124						
31	65.65	330	356	124	62.2	132	116	106	60	0	22.0	7.0	10.4

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Aug	Air	W	E		W	E	W	E	in.	in.	in.		W	E
1	73	73	73	475.1					0					
2	73	73	73	490.9			1	1	0					
3	74	77	76	657.7			1	1	0			87	92	91
4	74	75	75	694.7			1	1	0					
5	76	80	79	680.4			1	1	0		E	90	88	94
6	80	78	78	698.2			1	1	0 (0)	1.55	-1.55			
7				677.6					0					
8	98	82	91	677.4			1	1	0			91	92	95
9	80	78	77	640.1			1	1	0					
10	80	78	80	548.1			1	1	0			92	87	92
11	68	73	73	355.3			1	1	0					
12	75	75	74	537.1			1	1	0			92	85	91
13	70	73	73	669.8			1	1	0 (0)	1.63	E -1.63			
14				669.2					0					
15	71	71	71	403.8			1	1	0.02			93	89	93
16	80	78	80	531.1			1	1	0					
17	82	77	76	655.3			1	1	0			95	93	95
18				631.5					0					
19	76	78	77	615.3			1	1	0			92	88	93
20	70	74	74	650.6			1	1	0 (0.02)	1.68	E -1.66			
21				422.1					0.07					
22	59	65	65	265.3			1	1	0.04			95	87	92
23				168.7					0.19					
24	62	64	64	310.9			1	1	0.22			82	82	82
25				273.5					0.03					
26				420.7			1	1	0.01					
27				613.7			1	1	0.05 (0.61)	0.77	-0.16			
28				588.0					0					
29				525.4			1	1	0					
30				572.7					0					
31				142.1	2		1	1	0.01			85		

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2 pm	
Sept	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	66.7			126	63.2	202	100.9						
2	66.7	300	320	127	63.4	181	90.3	110	54	0	10.3	6.6	9.2
3	66.7			124	62.2	171	85.5						
4	66.7			122	60.8	162	81.6						
5	66.7	160	416	119	59.3	157	78.5	119	50	0	18	6.7	9.0
6	66.7			110	54.7	150	74.8						
7	22.2	250	292		50.6		69.4	132	63	0	12.5	6.9	8.7
8	22.2				48.5		62.5			0	9.0	6.8	8.2
9	22.2	520	194		50.3		56.8	126	82	0	13.2		
10	22.2				52.3		53.5			0	38.2	7.0	10.2
11	22.2				53.2		50.8						
12	22.8				53.9		48.8	87	78	0	12.7	7.2	9.1
13	22.8				55.0		46.2						
14	22.8	280			56.5		43.1	66	75	0	8.1		
15	22.8				61.7		39.5						
16	22.8	610			69.0		37.1	84	80	3.0	25.0	7.3	9.0
17	22.8				75.2		35.8						
18	22.8				78.2		35.5						
19	22.8	550			79.5		36.0	60	93	4.2	0	7.3	7.2
20	22.8				81.9		36.5						
21	23.2	575			86.0		37.1	63	85	6.4	9.7	7.4	7.8
22	23.2				89.3		37.7						
23	23.2	480			93.3		38.3		88	6.0	0.6	7.3	7.1
24	23.2				96.4		38.9						
25	23.2				95.8		39.6						
26	23.2	350	244		91.6		40.5	38	74	14.4	14.3	8.2	8.5
27	23.2				86.7		42.0						
28	23.7	400	350		81.2		44.5	36	77	25.6	18.3	9.4	9.4
29	23.7				78.8		48.7						
30	23.7	555	544		78.8		54.5	33	88	7.6	0.8	8.5	7.4

Period of recovery

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Sept	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1				291.2					0.02		E			
2	69	69	68	529.2	3		2	1	0.06 (0.09)	0.97	-0.88	94	76	88
3				408.1					0					
4				285.9					0.35					
5	66	72	72	398.6	4		2	1	T			80	77	88
6				580.8					0					
7	72	70	68	568.8	4		2	1	0			81	74	89
8				564.7					0			80	74	90
9	90	78	75	425.7	2		1	1	0 (0.35)	1.16	E -0.81	85	74	91
10	90	80	78	467.1	2		2	1	0					
11				455.0					T					
12	68	72	73	366.0	2		2	1	0			74	77	89
13				448.4					0					
14	73	73	72	405.7	2		3	1	0			85	79	85
15				406.0					0					
16	66	72	72	363.6	1		2	1	0					
17				263.4					0					
18				445.4					0		E			
19	62	66	65	228.9			2	1	0 (0)	1.46	-1.46			
20				490.2			2	1	0.09					
21	69	66	66	505.6			2	1	0				90	86
22				383.8					0					
23	66	64	64	204.0			2	1	0					
24				308.3			1	1	0					
25				375.7					0					
26	73	72	72	356.4			1	1	0					
27				370.2					0					
28	77	75	75	418.0			1	1	0				91	87
29				448.2					0					
30	88	70	72	422.2			1	1	0 (0.09)	1.43	E -1.34		89	83

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
Oct	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	23.7				78.2		59.4						
2	23.7				77.9		63.4						
3	24.1	480	230		77.9		66.6	33	60	5.4	0	8.7	7.2
4	24.1				78.7		68.9						
5	24.1				80.3		70.3			14.0	17.2	9.5	9.5
6	24.1				82.6		70.8						
7	24.1	100	216		85.9		69.3	29	67	0.7	0	7.3	7.2
8	24.1				90.3		70.2						
9	24.1				90.0		72.7						
10	24.5	480	730		91.1		76.6	50	55	2.8	5.2	7.7	7.4
11	24.5				91.2		76.7						
12	24.5		238		92.4		73.0			1.3	2.8	7.3	7.2
13	24.5				94.7		73.7						
14	24.5	630			97.8		78.9	27	52	6.2	11.0	8.1	8.7
15	24.5				98.1		82.0						
16	24.5			91	95.6	166	83.0						
17	32.2	450	358	180	90.3	164	82.1	32	102	8.2	15.8	7.8	9.0
18	48.2			173	86.3	156	78.2						
19	49.1	520	282	167	83.7	143	71.3	60	62	0	0	7.3	7.1
20	49.1			162	81	123	61.6						
21	49.1			155	77	114	56.8						
22	49.1			146	73	114	56.9						
23	49.1			136	68	108	53.8						
24	48.2	500	424	124	62.4	95	47.4	39	50	0	1.0	7.1	7.1
25	48.2			118	59	86	43.0						
26	48.2	110	280	116	58	81	40.6	45	53	0	0	7.0	7.1
27	48.2			120	60	81	40.6						
28	48.2	90	196	120	60.2	79	39.7	25	30	0	0	7.1	7.0
29	48.2			118	58.8	80	40.1						
30	48.2			114	57.3	83	41.8						
31	48.2	380	572	111	55.7	89	44.7	55	39	0	0	7.2	7.1

Period of recovery

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Oct	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1				415.0					0					
2				416.9					0					
3				244.9			1	1	0			76	88	82
4				385.5					0					
5	65	65	65	336.1			1	1	0					
6				244.7					0.22					
7	62	64	64	121.8			1	1	0.28		P		91	85
8				252.8					0.52 (1.02)	0.34	+0.68			
9				372.7					0.06					
10	63	58	57	397.7			1	1	0				85	84
11				69.2					0					
12	50	56	55	254.7			1	1	0.24				90	83
13				254.7					0.12					
14	64	58	61	322.0			1	1	0.01 (0.43)	0.57	E -0.14		87	86
15				313.0					0					
16				346.9					0					
17	74	66	65	330.9			1	1	0				89	83
18				228.1					0					
19	55	58	58	50.3			Δ	1	0				86	81
20				218.7					0					
21				121.9					0					
22				190.0					0					
23				64.8					T					
24	60	60	58	196.2	3	3	1	1	0.26			66	89	87
25				277.1					0					
26	60	58	58	203.8	3	3	1	1	0.11			82	87	83
27				56.2					0.28					
28	59	56	58	131.7	4	2	1	1	0.37 (1.02)	1.12	E -0.10	83	85	81
29				274.9					0.01					
30				105.1					0					
31	57	57	55	56.2	2	1	1	1	0.04				86	88

Date	Flow	Waste		10 day ave. load					Effluent Quality			
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD	DO at 2 pm		pH at 2 pm	
Nov	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	48.2			106	53.1	93.0	46.5						
2	48.2	196	1218	98	49.3	94.2	47.1	45	36	0	0.3	7.1	7.2
3	16.1				47.7	93.0	46.5						
4	16.4	546	308		48.6	92.0	46.0	43	25	0.5	6.8	7.1	7.4
5	16.4				48.9	92.6	46.3						
6	16.4				48.6	94.0	47.0						
7	16.4	357			47.7	96.2	48.1	36	32	0.8	7.7	7.1	7.8
8	16.4				48.0	94.8	47.4						
9	16.4	483	252		49.4	90.0	45.0	34	25	2.2	1.8	7.1	
10	16.4				49.4	81.0	40.5						
11	16.4	294	174		49.5	72.8	36.4	28	17	9.6	11.5	7.2	7.9
12	16.4				50.2	66.2	33.1						
13	16.4				48.3	61.4	30.7						
14	16.4	182			43.8	58.2	29.1	19	20	7.2	6.7	7.1	7.4
15	16.4				40.5	55.2	27.6						
16	16.1	238			38.3	52.6	26.3	17	18	12.2	11.3	7.9	7.8
17	16.1				36.8	50.4	25.2						
18	16.1				34.2	48.6	24.3			9.2	3.3		
19	16.1				30.7	47.2	23.6						
20	16.1				28.7	47.0	23.5						
21	16.1	70			27.6	47.6	23.8	7	17	10.3	8.4	7.3	7.5
22	16.1				27.0	48.4	24.2						
23	16.1				26.7	49.0	24.5						
24	16.1				26.7	49.6	24.8						
25	16.1	35			26.2	50.4	25.2	0	12	13.5	9.2		
26	72.4			51	25.4	51.0	25.5						
27	72.4			50	24.6	51.8	25.9						
28	72.4	105	148	48	23.8	52.6	26.3	14	12	15.3	13.4	8.6	8.5
29	72.4			49	24.6	55.2	27.6						
30	73.6	280	252	54	27.1	59.6	29.8	19	11	13.9	12.7		

Period of recovery

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960		°F		Data	Odor		Color		P	E		infl.	effluent	
Nov	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1				244.8					0.12					
2	50	54	54	86.9	4		1	1	0.06				86	87
3				277.4					0.36					
4	57	52	51	263.5	2		1	1	0		E		82	88
5				267.9					0 (0.59)	0.76	-0.17			
6				210.3					0					
7	56	50	50	109.4			1	1	0				85	89
8				216.6					0					
9	47	48	48	161.6			1	1	0				83	82
10				53.3					0.04		P			
11	53	50	51	150.2			1	1	1.21 (1.25)	0.42	+0.83		88	91
12				93.1					0.03					
13				214.2					0.30					
14	47	49	48	167.6			1	1	0.57			85	91	88
15				36.4					0.78					
16	54	52	53	150.5			1	1	0.32			81	90	86
17				37.5					0.09		P			
18	51	51	50	178.7			1	1	0.89 (2.98)	0.22	+2.76		91	89
19				52.2					0.11					
20				45.8					0.55					
21	47	48	48	121.5			1	1	0.54			90	93	91
22				63.5					0.09					
23				22.6					0.54					
24				10.5			1	1	2.07 (3.90)		P +4.85			
25	46	46	46	113.1					1.79					
26				97.1					0.03					
27				154.6					0					
28	41	45	46	114.8			1	1	0			79	94	92
29				103.1					0					
30	45	43	43	42.4			1	1	0.01				93	95

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1960	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
Dec	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	73.6			58	29.2	64	32						
2	73.6	224	236	62	30.9	68	34	19	14	5.8	6.5	7.1	7.4
3	73.6			65	32.7	70	35						
4	73.6			69	34.6	72	36						
5	73.6	228	174	73	36.6	74	37	17	13	2.0	5.6	7.1	7.4
6	73.6			78	39.3	78	39						
7	73.6	308	302	86	42.9	82	41	23	16	0.9	5.4		
8	73.6			94	47.1	88	44						
9	73.6	350	286	100	50.1	92	46	50	20	0.3	5.6	7.1	7.1
10	73.6			102	50.9	92	46						
11	73.6			102	51.1	90	45						
12	73.6	196	174	102	50.6	88	44	40	21	0.2	0.7	6.9	7.1
13	73.6			100	49.9	90	45						
14	73.6			98	48.9	94	47						
15	73.6			96	47.7	100	50						
16	72.4	146	442	92	45.5	108	54	48	36	0.1	0.3	6.7	7.0
17	72.4			86	42.5	110	55						
18	72.4			78	39.0	110	55						
19	72.4	56		70	35.0	108	54	32	35	0.4	0.85	7.0	7.0
20	71.0			64	31.6	104	52						
21	69.6	140	79	58	29.3	100	50	34	20	0.40	1.10	6.8	7.2
22	69.6			56	28.2	96	48						
23	69.6			54	27.3	88	44						
24	69.6	63	58	54	26.7	80	40	33	30	0.1	0.2	6.8	7.0
25	69.6			52	26.3	68	34						
26	69.6			52	26.1	54	27			0.3	0.9	6.5	6.9
27	69.6			52	26.9	42	21						
28	69.6	140	74	52	25.7	34	17	29	21	0	0.3	6.7	6.9
29	69.6			54	26.9	30	15						
30	68.3	238	212	56	28.4	32	16	47	21	0	0.4	6.7	6.9
31	68.3			60	30.1	36	18						

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1960	°F			Data	Odor		Color		P	E		infl.	effluent	
Dec	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1									0.08					
2	54	46	46				1	1	0.02 (1.93)	1.98	E -0.05	77	95	92
3				88.1					0.11					
4				165.2					0.06					
5	35	43	43	52.1			1	1	0.04			80	97	92
6				168.9					0					
7	44	42	42	185.7			1	1	0					
8				177.7					0					
9	41	40	40	137.7			1	1	0				91	90
10				38.2					0					
11				21.4					0.04					
12	64	47	45	157.0					0.17					
13				88.9					0.02					
14				82.6					0					
15				108.1					0					
16	41	44	43	39.5	2		4	1	0.10				88	88
17				29.3					0.80					
18				23.5					0.85					
19	54	47	46	76.6			4	1	0.58 (2.77)		P +2.86		88	92
20				56.3					0					
21	36	44	43	44.6	1		4	4	0				99	99
22				53.9					0					
23				44.1					0					
24	36	42	41	44.2	2	2	4	4	0 (0)	0.56	E -0.56		94	96
25				30.8					0.07					
26	50	45	44	127.3	3	3	4	4	0.27				95	97
27				105.6					0					
28	36	41	41	164.7	2	3	4	4	0				95	97.5
29				172.3	1	1			0					
30	30	39	39	51.1	1	1	4	4	0				95.5	97
									0.11 (0.45)	0.10	P +0.35	(79)	(92)	(91)

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2 pm		pH at 2 pm	
Jan	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	68.3			64	32.1	42	21						
2	66.7			69	34.4	46	23						
3	66.7	300		73	36.8	52	26	48	22	0.0	0.5	6.2	6.6
4	66.7			77	38.4	58	29						
5	66.7			75	37.4	62	31	63	23	0.2	1.2		
6	65.4			79	39.7	68	34						
7	65.4	98	146	78	38.7	74	34	53	26	0.02	0.06	6.70	6.85
8	65.4			74	37.2	70	35						
9	65.4			69	34.7	70	35						
10	65.4	63	188	64	31.8	70	35	6	6	2.6	7.0	7.1	7.2
11	64.0			59	29.5	70	35						
12	62.5	189	248	56	27.8	72	36	12	6	2.3	2.6	7.1	7.2
13	62.5			49	24.7	74	37						
14	64.0	49		42	21.2	76	38	35	16	0.8	4.3	6.70	6.95
15	85.4			39	19.7	78	39						
16	85.4			40	20.1	82	41						
17	85.4	203	226	45	22.3	84	42	31	16	4.8	12.0	7.0	7.4
18	85.4			49	24.3	86	43						
19	85.4	147	102	52	25.9	84	42	19	5	7.7	14.8		
20	83.4			53	26.6	84	42						
21	81.7	49	278	51	25.4	88	44	30	21	2.8	14.7	7.0	6.2
22	81.7			48	24.2	90	45						
23	81.7			50	24.8	90	45						
24	81.7	152	162	54	27.2	88	44	27	16	9.0	15.8	7.4	8.0
25	122.5			61	30.6	98	49						
26	122.5	245	502	70	35.1	120	60	17	12	9.7	18.0	7.3	8.1
27	118.8			76	38.0	138	69						
28	118.8	224	404	82	41.2	154	77	18	13	9.0	17.2	7.2	8.4
29	118.8			88	43.8	168	84						
30	122.5			92	46.2	172	86						
31	122.5	100	96	97	48.4	166	83	17	11	7.3	14.5	7.1	8.0

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961	°F			Data	Odor		Color		P	E		infl.	effluent
Jan	Air	W	E	gm cal / cm^2	W	E	W	E	in.	in.	in.		W E
1				64.7					T				
2				26.2					0.11				
3	36	40	39	57.9			4	4	0				
4				108.6					0			98	96.5
5				58.0	1		4	4	0.61				
6				43.5					0.84				
7	48	46	45	56.6			4	3	0.21 (1.17)	2.91	-1.14	88.5	94
8				32.2					0.66				
9				118.0					0.17				
10	54	49	49	96.9			3	2	0.01			94	94
11				38.1					0				
12	45	45	45	81.9			3	2	0.14		99	93	96
13				115.6					0.22				
14	46	48	46	76.9			2	2	0.26 (1.46)	0.18	+1.28	101 89	94
15				40.6					0.04				
16				80.1					0.08				
17	60	51	50	130.5			2	2	0.02				
18				199.8					0				
19	54	48	47	170.4			1	1	0		99	97	96
20				207.1					0				
21	43	45	45	205.5			1	1	0 (0.14)	0.14	0.00	99.5 96	97
22				215.1					0				
23				93.7					0.02				
24	43	46	46	162.7			2	1	0.01		98	93	95
25				--					0.01				
26	53	47	47	194.5			1	1	0		99	96	97
27				157.5					0				
28	55	50	47	202.3			1	1	0 (0.04)	0.39	-0.35	97	95
29				87.0					0.31				
30				57.4					0.27				
31	59	53	51	202.1			1	1	0.81				

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD /acre /day		SS /acre /day		BOD		DO at 2pm		pH at 2pm	
Feb	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	125.2			99	49.5								
2	125.2	75		99	49.5			26	15	11.1	12.3	7.2	8.1
3	125.2			95	47.7								
4	125.2	28		86	43.2			21	12	12.5	10.0	7.35	7.30
5	127.8			74	37.0								
6	125.0			64	31.8								
7	112.2	95		55	27.6								
8	112.2			48	23.9								
9	109.0	48		42	20.8								
10	141.0			37	18.3								
11	0	22		31	15.5			12	22	7.0	7.5	7.3	7.3
12	0			26	13.1								
13	0			23	11.5								
14	0			21	10.6								
15	112.1			19	9.6								
16	138.0	30		17	8.6								
17	138.0			15	7.3								
18	145.2	45		14	7.0			15	6	15.1	8.6	6.0	7.0
19	145.2			15	7.6								
20	145.2			18	9.2								
21	149.7			23	11.7								
22	149.7			29	14.5								
23	149.7			35	17.6								
24	154.0			42	20.9								
25	308.0	44	202	48	23.9			12	10	15.4	9.7	8.6	7.9
26	327.0												
27	327.0												
28	351.0	131											
29													
30													
31													

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961		°F		Data	Odor		Color		P	E		infl.	effluent
Feb.	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W E
1				49.4					T				
2	52	52	51	79.2			1	1	0.32			99	95 97
3				88.7					0.11				
4	53	53	52	86.9			1	1	0.05		+1.88		98 98.5
5				98.5					0.08				
6				177.4					0.64				
7				113.6					0				
8				91.9					0.11				
9				34.6					0.45				
10				29.9					2.76				
11	48	50	50	122.5			3	3	1.11 (5.10)	0.63	+4.47		98 100
12				99.0					0.36				
13				72.4					0.22				
14				129.4					0.24				
15				216.1					0.69				
16				196.8					0.06				
17				177.6					0.16				
18	44	48	47	137.4			1	1	0.05				88.5 83
19				126.9					0.16				
20				120.6					0.04				
21				88.1					0.05				
22				199.6					0.69				
23				190.7					0.04				
24				103.9					0				
25	49	47	47	221.8			1	2	0.85				
26				269.1					0.24				
27				253.0					0.44				
28				178.8					0.04				
29													
30													
31													

Evaporation pan washed out

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 2 pm		pH at 2 pm	
Mar	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	348.0	66		78.6	39.3								
2	348.0	60		84.9	42.4								
3	334.0			91.7	45.7								
4	308.0	48	36	96.8	48.4			18	9	9.9	12.8	7.6	8.0
5	308.0			100.7	50.4								
6	276.0	33	76	103.0	51.5								
7	271.0	36	96	104.0	52.0								
8	271.0			98.5	49.3								
9	264.0	60	32	90.1	45.1					5.2	15.2		
10	255.0			75.4	37.7								
11	248.0	12	78	65.1	32.5			5	8	7.3	14.8	7.1	8.3
12	226.0			57.1	28.6								
13	212.0			51.6	25.8	112.6	66.3						
14	204.0	46	63	48.9	24.5	113.6	56.8						
15	183			47.4	23.7	110.2	55.1						
16	144	59		47.1	23.6	103.0	51.5						
17	137			46.2	23.1	93.2	46.6						
18	125			43.3	21.7	79.9	40.0						
19	197			41.2	20.6	65.6	32.8						
20	248			44.2	22.1	55.9	28.0						
21	276	60	26	51.2	25.6	49.6	24.8			24.0	23.2	9.1	9.2
22	292			56.4	28.2	48.0	24.0						
23	292	54	66	59.5	29.8	50.5	25.3						
24	292			61.5	30.8	50.4	25.2						
25	285	45	22	63.3	31.7	48.1	24.1	18	13	18.8	19.3	8.6	8.9
26	269.0			66.4	33.2	56.2	28.1						
27	269.0			71.0	35.5	74.1	37.1						
28	269.0	72	218	77.3	38.7	102.0	51.0						
29	276.0			79.3	39.7	119.6	59.8						
30	269.0	42	80	77.4	33.7	126.8	63.4						
31	248			75.7	37.9	136.7	68.4						

Date 1961	Temperature F			Solar Data	Physical Appearance Odor		Color		Precip	Evap	P-E	Transmittancy infl.	effluent
Mar	Air	W	E	gm cal / cm^2	W	E	W	E	P in.	E in.	in.	W	E
1				118.3					0.68				
2				218.8					0.13				
3				180.6					0.05				
4	44	48	47	169.2			1	1	0.08 (1.66)	0.65	P** +1.01		
5				91.9					0.52				
6				230.0					1.14				
7				316.7			2	1	0.15				
8				161.6					T				
9				218.9			2	1	0.13				
10				131.1					0.26				
11	49	49	49	204.8			2	1	0.07 (3.17)				
12				178.3					0.20				
13				126.1					0.32				
14				97.0					0.29				
15				248.7					0.11				
16				158.6					0.01				
17				299.8					0.20				
18				403.7					0.07 (1.20)				
19				124.7					0.11				
20				302.9					0.46				
21	56	58	60	224.3			1	1	0.11				
22				276.4					0.23				
23				398.5					0.05				
24				325.8					0.21				
25	57	58	58	368.3			1	1	0.01 (1.18)	0.45	P +0.73		
26				174.7					0.16				
27				434.2					0.80				
28				471.9					T				
29				528.6					-				
30				400.0					-				
31				330.6					0.01				

**Net precipitation

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 2 pm		pH at 2 pm	
April	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	248	66	132	76	38	147	74	22	12	11.7	19.7	8.0	9.2
2	255			82	41	175	87						
3	264			94	57	229	115						
4	276.0	164	580	111	55	308	154						
5	294.0			130	65	365	183						
6	339.0	176	338	152	76	402	201						
7	334.0			175	87	438	219						
8	348.0	201	410	204	102	491	246	18	13	2.4	10.8	7.3	8.3
9	87.1			227	113	537	269						
10	118.5			242	121	572	286						
11	178.0	161	246	244	122	577	289						
12	178.0			248	124	559	280						
13	178.0	125	194	241	120	517	209						
14	182.0			234	117	473	237						
15	182.0	225	602	228	114	461	231	34	23	18.0	25.8	8.8	9.3
16	182.0			216	108	448	224						
17	182.0			197	98	419	210						
18	182.0	120	286	172	86	372	186						
19	186.0			155	77	333	167						
20	186.0	130	106	145	72	303	152						
21	186.0			140	70	388	144						
22	186.0	81	56	135	62	274	137	36	25	7.1	9.4	7.4	7.7
23	186.0			137	68	262	131						
24	186.0			140	70	232	116						
25	182.0	265	92	143	71	184	142						
26	182.0			151	75	150	75						
27	182.0	280	180	163	81	130	65						
28	178.0			170	85	118	59						
29	171.5	125	160	170	85	114	57	39	18	0	9.9	7.3	8.7
30	171.5			168	84	123	62						

Date 1961	Temperature F			Solar Data	Physical Appearance Odor		Color		Precip	Evap	P-E	Transmittancy	
April	Air	W	E	gm cal / cm²	W	E	W	E	P in.	E in.	in	infl. W	effluent E
1	63	60	60	388.8			1	1	T				
2				413.1					0				
3				428.0					0				
4				581.5					0				
5				575.3					0				
6				579.5					0				
7				562.5					0		E*		
8	51	56	57	481.2			1	1	0 (0.97)	1.97	-1.00		
9				407.7					0				
10				554.1					T				
11				437.8					0				
12				433.2					0.09				
13				313.8					0.03				
14				467.9					0.05		E		
15	60	64	64	454.1			1	1	0 (0.17)	0.94	-0.77		
16				327.0					0				
17				457.2					0.01				
18				172.2					0.11				
19				294.4					0.21				
20				283.4					0.14				
21				189.5					0.42		P**		
22	50	52	52	283.1			1	1	0.41 (1.30)	0.81	+0.49		
23				160.9					0.09				
24				436.4					0.02				
25				520.8					T				
26				482.9					0				
27				564.8					0				
28				368.5					0		P		
29	55	61	61	396.1	2		2	1	0.26 (0.37)	0.33	+0.04		
30				378.2					0.39				
31													

* Net evaporation
**Net precipitation

Date	Flow	Waste		10 day ave. load				Effluent Quality					
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 2 pm		pH at 2 pm	
May	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	171.0			169	85	140	70						
2	171.0	120	330	172	86	163	82						
3	171.0			169	85	182	91						
4	174.0	115	230	160	80	195	98						
5	174.0			147	73	227	114						
6	174.0	160	678	136	68	276	138	44	23	6.6	18.1	7.4	8.5
7	128.0			123	62	314	157						
8	128.0			116	58	349	175						
9	128.0	155	672	115	58	379	190						
10	128.0			113	57	393	197						
11	133.0	99	304	109	54	390	195						
12	133.0			107	53	385	183						
13	137.0	140	416	106	53	390	195			6.7	18.0	7.5	8.8
14	137.0			105	53	385	193						
15	137.0			102	51	357	179						
16	137.0	111	136	95	48	305	153						
17	133.0			91	46	259	129						
18	133.0	132	148	88	44	219	109						
19	133.0			88	44	188	94						
20	131.0			90	45	171	86						
21	133.0			94	47	169	84						
22	59.4			97	49	166	83						
23	133.0	178	362	99	50	162	81						
24	68.5			102	51	171	86						
25	68.5			106	53	184	92						
26	137.0			110	55	200	100						
27	133.0			114	57	216	108						
28	133.0			118	59	233	117						
29	133.0			121	61	246	123						
30	133.0			124	62	256	128	34	48	13.3	16.1	8.5	9.5
31	133.0			127	64	264	132						

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961	F			Data	Odor		Color		P	E		infl.	effluent
May	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W E
1				399.1					0.25				
2				447.8					0.13				
3				479.6					0.04				
4				461.3					0.13				
5				234.1					0.01		P**		
6	56	59	60	394.3			1	1	0.08 (1.03)	0.91	+0.12		
7				383.3					0.09				
8				315.0					T				
9				286.5					0.16				
10				402.1					0.20				
11				417.8					0.33				
12				334.6					0.01		P		
13	58	60	61	346.8			1	1	0 (0.79)	0.30	+0.49		
14				345.4					0.06				
15				624.5					0.05				
16				683.3					0				
17				660.6					0				
18				720.4					0				
19				715.3					0		E*		
20				-					T (0.11)	0.63	-0.52		
21				-					0.26				
22				330.4					T				
23				605.7					0.05				
24				705.3					0.02				
25				708.7					0				
26				289.5					0.05		E		
27				640.2			1	1	0.13 (0.51)	1.19	-0.68		
28				600.2					0				
29				572.3					00				
30	59	64	64	569.2			1	1	T				
31				699.2					0				

* Net evaporation
**Net precipitation

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 2 pm		pH at 2 pm	
June	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	133.0			129	65	270	135						
2	131.0			130	65	272	136						
3	131.0	205	408	132	66	275	138			0.5	5.5	7.4	8.9
4	133.0			134	67	282	141						
5	133.0			137	68	293	147						
6	139.5		600	141	71	310	155						
7	46.4			134	67	297	148						
8	142.0	250	530	140	70	310	155						
9	142.0			144	72	316	158						
10	139.5	230	560	148	74	334	167	70	52	10.2	6.6	8.4	8.8
11	139.5			152	76	347	174						
12	139.5	350		163	82	359	179						
13				178	89	372	186						
Second phase changed to series loading													
14	57.2	438		195	20			44	44	3.0	9.9	7.6	9.2
21	51.5	80	98	32	7.0	39		48	34	0.3	0.8	7.8	8.6
24	51.5	85		34									
28	45.0	21		7.0	7.0			20	20	3.8	7.7	7.8	8.4
										DO at 9 am		pH at 9 am	
July													
5	43.2	65	46	22.0		15		*136	28	0.6	0.1	8.2	8.7
7	73.5	115		65.8									
10	73.5	72		41.2									
12	75.0	20	65	32.4	17	38		34	32	2.8	3.1	9.3	9.6
14	75.0	57		35.3									
19	73.5	180	84	48.8	25	48		42	30	8.7	10.9	8.7	10.0
21	72.5	180		69.1									
24	70.5	80		79.0									
26	92.0	90	126	77.8	28	71		46	30	14	66.6	9.3	8.8
31	70.5	75		53									

*Not representative high concentration of aquatic forms

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy		
1961		F		Data	Odor		Color		P	E		infl.	effluent	
June	Air	W	E	gm cal / cm²	W	E	W	E	in.	in.	in.		W	E
1				727.4					0					
2				405.5					0		E*			
3		69	69	595.0			1	1	0	1.12	-1.12			
4				662.4					0					
5				476.4					0					
6				321.5					0.10					
7				738.0					0.03					
8				447.3					0					
9				409.8					0.09		E			
10	-	67	68	508.3			1	1	0.07 / (0.22)	0.83	-0.61			
11				239.7					0.06					
12				714.6					0.09					
13				-					0					
Second phase changed to series loading														
14	70	70	71	477.2							E	89	77	84
19				669.5					(0.15)	1.96	-1.81			
21	59	69	69	708.3			1	1			E	96	81	79
23				767.9					(0)	1.18	-1.18			
28	59	66	67	689.1			1	1	0		E	98	85	88
29									T / T	1.47	-1.47			
July														
5	66	66	66	618.8			1	1	0.46	1.47	E -1.01	90	85	83
12	86	79	80	682.2					0.17	1.60	E -1.43	93	88	83
19	72	74	76	655.0			1	1	0	1.67	E -1.67	72	82	83
26	74	75	73	653.0			1	1	0	1.68	E -1.68	77	82	86

*Net evaporation

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 9 am		pH at 9 am	
Aug	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
2	70.5	180	192	55.3	8	105		26	34	4.6	9.6	8.8	9.7
9	91.8	90	188	85.0	9	134		20	22	0.2	2.9	8.0	9.0
14	280.5	65		87.6									
15	181.5	65		87.4									
16	24.7	65		81.9	33			26	40				
21	97.2	157	169	92.5		128							
23	97.2	175		107.4	89			144	48	9.6	4.6	9.0	9.0
30	97.2	256	232	164.0	60	175		102	65			7.6	8.8
Sept													
2					155								
4	106.2	181		49	148.0			91	60				
5	0				0								
6					5.3								
7	110.9	350			303								
8	56.6	406	300		179.1								
9	42.1	364	192	24	119			58	67				
13	14.6			61.9				40	67			7.2	7.2
15	14.6			55.1	19			34	39				
21	20.9	120		30.6	6.0			23	18				
27	20.9	119		21.5	5			17	19		1.5		7.6
29	20.9	238		23.8	5			27	18		7.3		7.2
Oct													
2	20.9	73		22.2	8			25	30		9.9		8.2
4	20.9	72		20.6							13.8		8.9
6	20.9	70		19.0	4			14	12		8.9		8.5
9	20.9	113		14.1									7.9
11	20.9	97		13.8							7.7		7.9
13	20.9	80.5		14.2					16		8.9		8.5
16	20.9	182		17.9							14.6		9.5
18	20.9	112		19.2							13.2		9.3
20	48.8	44		20.2							10.1		8.8
23	48.8	56		21.9	3			10	6		9.9		9.0
25	48.8	60		22.1							15.3		9.0
27	48.8	64		21.5							6.3		9.0
30	48.8	70		22.8	3			11	9		12.5		9.0
31	32.6	85		19.3							10.9		8.7

Date	Temperature F			Solar Data	Physical Appearance Odor		Color		Precip	Evap	P-E		Transmittancy	
1961									P	E		infl.	effluent	
Aug	Air	W	E	$\frac{gm\ cal}{cm^2}$	W	E	W	E	in.	in.	in.		W	E
											E*			
2	75	72	73	633.5			1	1	0	1.27	-1.27	68	83	80
7				678.9					0	1.93	-1.93			
9	65	72	70	581.9			2	1	0	0.60	-0.60	79	81	84
14							2	1	0					
16	68	69	69	435.3	1		2	1	T	1.48	-1.48			
23	76	78	74	549.5	1		3	1	0	1.31	-1.31		78	81
30	83	79	78	456.7	3		3	1	0.18	1.32	-1.14	35	64	80
Sept														
6				550.7	2	2	1	1	0.79	1.46	-0.67			
13	64	66	64	452.9			1	1	0	1.42	-1.42	38	72	70
27	56		60	355.9			2	1	0.40	1.56	-1.06			
29	51		58	346.7			1	1	(0.04)	0.30	-0.26			
Oct														
2	60		62	396.0			1	1		0.38	-0.38			
4	57		60	396.1			1	1		0.26	-0.26			
6	57		61	321.6			1	1	0	0.16	-0.16			
9	52		55	280.3			1	1	(0.14)	0.22	-0.36			
											P**			
11	52		55	146.0			1	1	(1.05)	0.34	+0.71			
13	60		58	164.7			1	1	T		E			
16	54		61	256.5			1	1	(0.26)	0.34	-0.06			
18	58		56	317.2			1	1	0	0.26	-0.26			
20	50		41	152.2			1	1	0	0.04	-0.04			
											P			
23	55		52	138.3			1	1	(0.98)	0.48	+0.50			
											E			
25	54		54	185.2			1	1	0.07	0.11	-0.04			
									0.85		P			
27	48		50	146.3			1	1	$(1_0 07)$	0	+1.10			
30	48		48	244.5			1	1	(0.27)	0.19	+0.08			

* Net evaporation

**Net precipitation

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1961	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 9 am		pH at 9 am	
Nov	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	48.8	86.0		25.3							13.6		9.0
3	48.8	66.5		26.5	5			12	16		11.8		8.9
8	48.8	121.0	840	33.3		320					14.4		
10	48.8	143	504	38.1	4	190	38.1	15	6		11.5		8.8
13	83.7	175	518	57.3		336	57.3				9.1		8.3
15	83.7	144	455	70.8		297	70.8				10.5		7.8
17	83.7	112	356	78.4	15	232	78.4	21	14		11.2		7.8
20	83.7	65	606	79.1		394							
22	30	33	580	73.5		145					9.0		7.6
25	83.7	24	112	55.1	15			23	18		8.4		7.3
Dec													
1	83.2	35.0		23.0									
7	83.2	36.0		24									
14	83.2	37.0		24.0									
20	83.2	37.0		24.0									
21	114.2	37.0		24.9									
22	222.0	35.0		28.6							7.9		7.3
26	124.8	29.9		28.1									
28	166.3	27.3		31.7							8.1		7.3
30	83.2	39		30.7							8.3		7.4

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1961		F		Data	Odor		Color		P	E		infl.	effluent
Nov	Air	W	E	$\frac{gm\ cal}{cm^2}$	W	E	W	E	in.	in.	in.	W	E
											P**		
1	51	50	50	150.2					(0.09)	0.18	+0.08		
											P		
3	52	50	50	133.7			1	1	(0.30)	0.26	+0.04		
									0		E*		
8	38	43	43	222.3			1	1	(0.01)	0.21	-0.20		
									0.24		P		
10	52	49	49	157.7			2	1	(0.24)	0.20	+0.04		
											P		
13	37	43	43	123.8			3	1	(0.15)	0.12	+0.03		
									0		E		
15	40	43	43	191.0			3	1	(0.16)	0.28	-0.12		
17	28	38	38	173.0			2	1	0				
											E		
20	28	38	38	82.4			2	1	0.18	0.24	-0.06		
									2.37		P		
22	50	46	46	21.9			0	1	(2.41)	0	+2.48		
									0.73		P		
24	39	43	43	31.5			2	1	1.38	0	+1.56		
Dec													
1	42			66.2			2	1	(1.38)				
8	35			86.6			2	1	(0.67)				
15	32			86.5			2	1	(0.16)				
22	41			54.7			2	1	(4.66)				
29	47			99.2			1	1	(0.67)				

* Net evaporation

**Net precipitation

Date	Flow	Waste		10 day ave. load						Effluent Quality			
1962	1000	analysis		BOD/acre/day		SS/acre/day		BOD		DO at 9 am		pH at 10 am	
Jan	gal	BOD	SS	W	E	W	E	W	E	W	E	W	E
1	82.0	50		35.0									
5	82.0	72		34.5									8.2
10	82.0	162		50.4							13.3		8.8
15	82.0	45		50.3							14.0		8.3
19*	82.0	60		42.0									
20	0												
21	0												
22	0												
23	0												
24	82.0	56.0		35.6									
25	111.0	55		37.0									
29	82.0	33		34.8							4.4		7.7
Feb													
3	82.0	32.2		26.8							7.3		7.2
9	82.0	29		19.9							5.8		7.4
13	124.8	16.2		18.0							9.8		7.9
16	124.8	15		16.5							10.0		8.1
19	124.8	16		15.4									7.4
23	138.8	52		23.4									
27	152	88		52.5									

*Lagoon frozen January 19th to 28th

Date	Temperature			Solar	Physical Appearance				Precip	Evap	P-E	Transmittancy	
1962		F		Data	Odor		Color		P	E		infl.	effluent
Jan	Air	W	E	$\frac{gm\,cal}{cm^2}$	W	E	W	E	in.	in.	in.	W	E
5	39		42	63.6			1	1	(0.28)				
10	37		42	143.7			1	1	(0.33)		P**		
15	35		40	88.5			1	1	(0.17)	0	+0.29		
											E*		
18									(0.04)	0.06	-0.02		
19***											E		
26									(0.44)	1.76	-1.32		
29	34		39	132.1			2	2					
Feb													
1				159.1									
											P		
3	39		40	141.0			2	1	(0.02)	0	+0.82		
											P		
9	43			78.1			1	1	(1.14)	0.49	+0.65		
10	45			119.0							P		
13	41			105.1			1	1	(1.16)	1.14	+0.02		
16	41			202.5			1	1			P		
19	39			142.2			1	1	(1.03)	1.01	+0.02		
											E		
24				240.2					(0.35)	0.72	-0.37		
28				271.5					0.14				

* Net evaporation

** Net precipitation

***Lagoon frozen January 19th to 28th

Date	Plankton Data						Bacteriological		Cl2 Requirement mg/L			
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		0.5 res. at 30 min.			
Apr	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13	222	260	0.16	0.12	M	E						
14												
15												
16		425	0.11	0.10	F	DMS						
17												
18												
19												
20			0.08	0.09	EMS	EMS						
21												
22								20	100,000			
23			0.10	0.10	MS	MS			5,300			
24												
25												
26												
27												
28												
29												
30			0.11	0.12	REM	REM						

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
May	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2												
3												
4												
5												
6					R	R						
7						R						
8												
9												
10												
11			0.09	0.08	B	B						
12												
13												
14												
15												
16												
17												
18	77	119	0.14	0.13	M	M						
19												
20												
21	102	212	0.16	0.17	M	AM						
22												
23												
24												
25			0.14	0.12	BE	BE						
26												
27												
28												
29												
30												
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res at 30 min.		
June	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1			0.05	0.04	B	B						
2												
3												
4			0.06	0.04	B	BES						
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20	410	445	0.08	0.10	BS	BS	7000	10,000	17,000			
21												
22												
23	400	330	0.12	0.16	BES	BS						
24			0.13	0,14								
25												
26												
27												
28			0.09	0.14			33,000		1,000			
29	186	706	0.03	0.11	BS	BES						

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
July	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2												
3												
4												
5												
6	66	510	0.04	0.11	BS	BES						
7												
8	166	497	0.07	0.14	BES	MES						
9	492	532	0.04	0.2	BEJ	BMS						
10												
11												
12	106	93	0.06	0.17	E	BEJ						
13												
14							380	315	4,000			
15	153	40	0.05	0.03	BEJ	MS						
16												
17												
18												
19	100	53	0.06	0.02	BCS	BCS						
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												
31												

Date	Plankton Data						Bacteriological		Cl_2 Reqmt mg/L			
1960	Cells/mm2		Wet Vol 1/100		Specie		Coliform/ml		0.5 res. at 30 min.			
Aug	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1	630	700	0.01	0.09	BE	BEC	1650	200		6.0	6.0	6.0
2												
3	450	292	0.13	0.14	BE	BE	1020	420	7,000			
4												
5	517	485	0.14	0.11	BCE	BCE	6000	2040	7,000			
6												
7												
8	1120	678	0.12	0.09	BCE	BES	2900	700	35,000	6.0	9.0	5.0
9												
10	680	660	0.13	0.11	BCE	BCES	2460	2600	70,000			
11												
12	580	500	0.14	0.11	BCE	BCE	2900	2300	180,000			
13												
14												
15	570	530	0.14	0.17	BCE	BES	1180	600	25,000	6.0	6.0	10.0
16												
17	600	470	0.11	0.10	BCE	BES	3600	1500	17,000			
18												
19	1040	470	0.14	0.13	BES	BCER	3400	1600		5.0	8.0	4.0
20												
21												
22			0.25	0.27	BE	BES				7.0	7.5	7.5
23												
24	350	100	0.17	0.15	BE	BES	350	100	28,000			
25												
26	400	630			BC	BES						
27												
28												
29	260	510	0.10	0.09	BESR	BES	3800	7900	160,000	13.5	13.5	
30												
31	320	740	0.17	0.22	BER	BERS	1800	650	70,000	10.5	16.0	13.0

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Sept	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2	880	390	0.15	0.30	BE	BERS						
3												
4												
5	420	1160	0.07	0.23	B	BRS				6.0	12.0	6.0
6												
7	420	1080	0.05	0.50	B	BES						
8	370	940	0.04	0.40	B	BERS						
9												
10												
11												
12	500	1040	0.07	0.35	BR	BERS	650	8000	44,000	6.0	8.4	
13												
14	490	1140	0.09	0.34	BERP	BECS		900	21,000			
15												
16	510	690	0.08	0.40	BEC	BECS	200	1750	36,000			
17												
18												
19	660	960	0.13	0.80	BES	BRS				3.0	9.0	9.0
20												
21	700	1020	0.10	0.70	BES	BES	170	1800	11,000			
22												
23	440	1020	0.17	0.22	BES	BES						
24												
25												
26	740	870	0.17	0.22	BES	BES						
27												
28	490	810	0.14	0.22	BES	BCS						
29												
30	410	940	0.17	0.32	BES	BRS						
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/ mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Oct	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2												
3	230	630	0.26	0.14	BCS	BJS						
4												
5												
6												
7	120	850	0.08	0.22	BRS	BCS						
8												
9												
10	140	530	0.12	0.30	BS	BS						
11												
12			0.12	0.28								
13												
14	230	420	0.10	0.26	BS	BCS						
15												
16												
17	30	400	0.08	0.22	EJS	BRS						
18												
19	40	450	0.08	0.24	BJS	BJRS						
20												
21												
22												
23												
24	80	420	0.06	0.16	BS	BRS						
25												
26	40	340	0.06	0.16	BS	BRS						
27												
28	50	330	0.05	0.15	BS	BRS	1200	130	16,000	3	3	2
29												
30												
31	160	330	0.11	0.13	BG	BRS						

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Nov.	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2	240	450	0.05	0.14	BGS	BGS						
3												
4	230	300	0.04	0.13	BS	BRS						
5												
6												
7	340	360	0.04	0.11	BGS	BRS G						
8												
9	270	240	0.05	0.10	BGS	BRS GT						
10												
11	460	200	0.09	0.12	BGS	BEG S		50	2000			
13												
14	210	290	0.08	0.13	BES	BHS						
15												
16	210	290	0.08	0.07	BES	BES						
17												
18												
19												
20												
21	110	210	0.06	0.07	BES	BRG S						
22												
23												
24												
25	170	290			BRS	BRS						
26												
27												
28	200	300	0.025	0.04	BES	BCS						
29												
30	190	300	0.03	0.04	BES	BES						
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1960	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Dec.	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2	150	210	0.03	0.105	BRES TG	BRS						
3												
4												
5	150	170	0.02	0.04	BGS	BES						
6												
7			0.01	0.04								
8												
9	60	120	0.02	0.03	BSG	BSG						
10												
11												
12	70	110	0.01	0.02	BG	CRSG						
13												
14												
15												
16	80		0.02		EG	CGRST						
17												
18												
19	20	100	0.02	0.04	R	EGR ST	240	45	5,000	4	2	2
20												
21			0.02	0.03								
22												
23												
24			0.03	0.03						2.8	2	5
25												
26			0.02	0.03								
27												
28			0.02	0.03								
29												
30			0.03	0.03			1400	60	77,000			
31												

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1961	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Jan	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2												
3			0.03	0.02								
4												
5												
6												
7	80	180	0.03	0.04	RET	STB	2200	240	3000	2	2	3
8												
9												
10	90	150	0.03	0.04	REG	BEC G						
11												
12	80	180	0.02	0.02	ESRG	BEG S						
13												
14	110	170	0.04	0.06	GRES	BER GS	240	320	3000	2	2	3
15												
16												
17			0.03	0.04								
18												
19			0.04	0.06								
20												
21			0.04	0.03								
22												
23												
24			0.04	0.06								
25												
26			0.04	0.08								
27												
28	150	250	0.05	0.06	CES	CES	15	15	2500			
29												
30												
31			0.04	0.06								

Date	Plankton Data						Bacteriological			Cl_2 Reqmt mg/L		
1961	Cells/mm²		Wet Vol 1/100		Specie		Coliform/ml			0.5 res. at 30 min.		
Feb.	W	E	W	E	W	E	W	E	Raw	W	E	Raw
1												
2	110	200	0.08	0.12	EGC	CES						
3												
4			0.05	0.06						2.5	2	7
5												
6												
7												
8												
9												
10												
11			0.04	0.05								
12												
13												
14												
15												
16												
17												
18	80	110	0.02	0.03	CSG ER	ER	10	9	8			
19												
20												
21												
22												
23												
24												
25	80	120	0.03	0.03	CEG S	CEG S	300	10	100	0.5	2	2
26												
27												
28												
29												
30												
31												

Date			Plankton Data				Bacteriological		cl2 Req'mt			mg/L
1961	Cells/mm^2		Wet Vol 1/100		Specie		Coliform/ml		0.5 res. at 30 min.			
Mar	W	E	W	E	W	E	W	E	Raw	W	E	Raw
4	30	70	0.02	0.04	E	S	70	20	200	3.0	2.0	
11			0.02	0.05			55	10	1,350	1.5	1.5	2.0
18										1.0	2.0	1.0
25			0.06	0.06			300	10	100	2.0	3.5	1.4
April												
1			0.04	0.05			60	1	1,500	1.5	2.5	2.0
8			0.03	0.05						2.5	2.5	2.5
15			0.05	0.06						2.0	2.5	2.0
22			0.03	0.06						5.0	5.0	3.5
25							50	20	5,000			
29							50	3	300	2.5	3.0	2.5
30	33	112	0.03	0.05								
May												
6			0.04	0.05			44	40	1,500	3.0	2.5	2.5
13	110	210	0.07	0.10			8	5	250	3.0	2.5	2.0
30	210	340	0.09	0.07								
June												
10			0.22	0.10								
Change to series**												
14	310	430	0.08	0.10			1,300	750	730,000	4.0	4.0	16.0
21	340	360	0.07	0.10			1,500	300	35,000	2.5	2.4	1.4
28	230	220		0.09						3.0	3.5	2.5
July												
5	350	340	0.09	0.07	SB	ES	5,600	300	13,000	4.5	4.0	4.0
12	520	540	0.09	0.09	ESB	BS				7.0	8.0	3.0
19	540	550	0.11	0.14	EJSB	BJS	28,000	3,000	200,000	3.0	12.0	4.5
26	630	580	0.12	0.14	EJS	EJS	2,500	3,100	380,000	6.0	7.0	2.5
August												
2	620	610	0.14	0.17	SE	SEB	4,000	1,500	30,000	9	7	5
9	190	490	0.05	0.17	SE	SEB	7,000	100	700,000	3	10	4
16	200	460	0.06	0.21	SB	ES	90	200	8,000	3	6	3
23			0.16	0.13	E	ES				4	4	7
30			0.06	0.08								
September												
13			0.10	0.08								

**Series loading West to East cell

Five-Day Biochemical Oxygen Demand of Effluent by Three Methods*

1960	West cell effluent			East cell effluent		
	Straight	Heat-killed		Straight	Heat-killed	
July	Unfiltered	Filtered	Unfiltered	Unfiltered	Filtered	Unfiltered
25	51	42	50	53	22	42
27	34	40	50	42	-	50
29	37	46	66	53	56	62
1960 Aug						
1	40	23	38	26	24	32
3	38	52	54	52	47	58
5	52	51	-	68	-	-
8	54	-	78	46	-	42
10	37	44	110	36	36	74
12	49	48	108	47	45	126
15	48	57	110	39	36	57
17	57	60	99	42	-	90
19	70	-	-	39	-	-
22	57	33	84	39	27	33
24	32	42	96	28	39	78
26	51	57	111	57	63	138
31	106	60	105	60	33	108
1960 Sept						
2	110	102	132	54	57	135
5	119	87	90	50	33	96
7	-	108	126	63	30	87
9	126	-	126	82	102	128
14	66	54	105	75	51	120
16	84	72	108	80	48	-
21	63	39	75	85	30	123
23	-	-	-	88	50	140
26	38	42	81	74	42	120
28	36	42	89	77	42	120
30	33	33	64	88	51	140
1960 Oct						
3	33	21	69	60	30	72
7	29	27	42	67	45	105
10	50	30	-	55	36	114
14	27	33	36	52	33	111
19	60	33	36	62	33	75
28	25	-	72	30	-	72
31	55	33	48	39	20	60

Five-Day Biochemical Oxygen Demand of Effluent (cont'd)

	West cell effluent			East cell effluent		
1960	Straight	Heat-killed		Straight	Heat-killed	
Nov	Unfiltered	Filtered	Unfiltered	Unfiltered	Filtered	Unfiltered
2	45	30	51	36	-	42
9	34	27	60	25	30	57
11	23	33	54	17	36	45
14	19	18	30	20	15	75
16	17	-	30	18	-	24
28	14	-	12	12	-	24
30	19	21	30	11	6	24
1960 Dec						
2	19	27	27	14	21	24
7	23	18	27	16	18	27
16	48	52	57	36	38	41
1961 Jan						
12	12	9	15	6	9	18
	31	9	24	16	6	12
19	19	15	30	5	15	30
24	27	16	27	16	11	14
26	17	15	21	-	-	-
31	17	12	27	11	15	24
1961 Feb						
4	21	10	31	12	3	25
1961 Mar						
25	18	16	20	13	8	-
1961 April						
1	22	18	26	12	8	24
8	18	12	32	13	12	32
15	34	16	44	23	18	48
22	36	26	36	25	14	42
29	39	-	-	18	-	-
1961 May						
6	44	-	-	23	-	-
30	34	51	60	48	62	81

Five-Day Biochemical Oxygen Demand of Effluent (cont'd)

1961	West cell effluent			East cell effluent		
	Straight	Heat-killed		Straight	Heat-killed	
June	Unfiltered	Filtered	Unfiltered	Unfiltered	Filtered	Unfiltered
10	70	40	90	52	28	81
**						
14	44	40	70	44	36	66
21	48	28	56	34	23	30
28	20	24	44	20	16	20
1961 July						
5	136	72	140	28	24	58
12	34	43	58	32	38	64
19	42	35	63	30	34	52
26	46	-	-	30	-	-
1961 Aug						
2	26	-	-	34	-	-
9	20	-	-	22	-	-
16	26	-	-	40	-	-
23	144	-	-	48	-	-
30	102	-	-	65	-	-

*Results reported in mg/L

** Series operated West to East cell